PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CXII.—No. 2907.] *LONDON: FRIDAY, SEPTEMBER 16, 1921.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 4½d.

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9030
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See Advertisement page 46, Sept. 9. 9402

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See Advt. Page 96, Sept. 9.
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City Hall, Cardiff. S 58

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Full-Time Day Courses in the Theory and Practice of Civil, Mechanical, and Electrical Engineering. The Courses in Civil and Mechanical Engineering include specialization in Automobile and Aeronautical Engineering, and those in Electrical Engineering include specialization in RADIO-TELEGRAPHY.
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The Laboratories, both Mechanical and Electrical, are well equipped with modern apparatus which, on the Mechanical side, provides, for specialization in Automobile and Aeronautical Engineering and, on the Electrical side, for specialization in Alternate and Continuous Current Work, in Radio-Telegraphy and Telephonym and in Electrical Testing.
Particulars as to fees, dates, etc., and all information respecting the work of the Institute can be obtained at the Institute or on application to:
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The East Indian Railway Company is prepared to receive

Tenders for the Supply and

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22 LOCOMOTIVE GOODS ENGINES AND TENDERS (2-8-0 type), as per specification to be seen at the Company's Offices.
Tenders are to sent to the undersigned, marked "Tender for Locomotives," not later than Eleven o'clock a.m., on Wednesday, the 12th October proximo.
The Company reserves to itself the right to divide the order, also to decline any Tender without assigning a reason, and does not bind itself to accept the lowest or any tender.
For each specification a fee of £1 1s. is charged, which cannot under any circumstances be returned.
By Order,
G. H. LILLIE,
Secretary.
Nicholas Lane, London, E.C. 4.
14th September, 1921. S 31

SOUTH STAFFORDSHIRE WATERWORKS COMPANY.

REINFORCED CONCRETE SERVICE RESERVOIRS.

The Chairman and Directors invite

Tenders from Reinforced

Concrete Specialists and Contractors, for CONSTRUCTING TWO WATERTIGHT REINFORCED CONCRETE COVERED SERVICE RESERVOIRS of One million gallons and Five million gallons capacity respectively, at Dudley.
Firms wishing to Tender may obtain particulars and plans from the undersigned.
The lowest or any Tender will not necessarily be accepted and only Tenders from Firms who have carried out similar work will be considered.
FRED J. DIXON, M.Inst C.E.,
Engineer-in Chief.
326A, Paradise Street, Birmingham.
September, 1921. S 57

COUNTY BOROUGH OF BELFAST.

ELECTRICITY DEPARTMENT.

The Corporation invite fresh

Tenders for the Manufacture,

DELIVERY and ERECTION, at the New Harbour Power Station, Belfast, of EXTRA HIGH PRESSURE and LOW PRESSURE SWITCHGEAR under "Section L."
The Specification and other particulars *already issued* by Messrs. PREECE, CARDEW & RIDER, 8, Queen Anne's Gate, Westminster, S.W. 1, and by Mr. T. W. BLOXAM, M.I.E.E., City Electrical Engineer, Belfast, *shall be the basis of the Tenders now called for, which may take the form of a covering letter.*
Tenders must be lodged in the Town Clerk's Office, City Hall, Belfast, not later than the 19th September, 1921.
The lowest or any Tender will not necessarily be accepted.
An official receipt must be obtained for every Tender delivered by hand. Tenders sent by post must be registered.
(Signed) R. MEYER,
Town Clerk.
7th September, 1921. S 59

SIAMESE STATE RAILWAYS.

Tenders are Invited for the

SUPPLY of SUPERSTRUCTURES of STEEL RAILWAY BRIDGES.
Specifications and drawings may be obtained against payment of 10/- from Messrs. C. P. SANDBERG, 40, Grosvenor Gardens, London, S.W. 1.
Sealed Tenders with the inscription "Tender for Railway Bridges 2464" must be forwarded to the undersigned, at whose offices in Bangkok, Siam, they will be received up to 2 p.m. on the 31st day of December, 1921.
Right is reserved to reject any or all Tenders, and to accept part of any Tender which is deemed to be most favourable to the interests of the Siamese State Railways.
Bangkok 1921.
PURACHATRA,
Commissioner General of Siamese State Railways. S 32

NOTTINGHAM CORPORATION.

The Nottingham Corporation is prepared to receive

Tenders for the Under-

mentioned ENGINEERING WORKS, in connection with the North Milford Power Station, viz.:—
SECTION "A."—The Manufacture, Delivery, Erection and Maintenance of:—
(a) Three 10,000 Kilowatt turbo-alternators, for a speed of 1500 revolutions per minute, with exciters, condensers, auxiliary plant, &c.
(b) One 1000 Kilowatt combined turbo-generator-alternator, with condenser, auxiliary plant, &c.
SECTION "B."—The Manufacture, Delivery, Erection and Maintenance of Six Water-tube Boilers, with Mechanical Stokers, Superheaters, Forced draught Fans, &c.
Specifications, General Conditions, and Forms of Tender, may be obtained from Messrs. PREECE, CARDEW & RIDER, 8, Queen Anne's Gate, Westminster, S.W. 1, on payment of a deposit of £5 for each section, which will be refunded on receipt of a *bona fide* Tender within the prescribed time.
Extra copies of the Specifications may be obtained on payment of 10/- for each copy, which will not be returnable.
Sealed Tenders, endorsed "Electricity Department, Tender for Generating Plant" (or Boiler Plant, as the case may be), must be delivered to me at my office before TEN a.m. on Friday, 21st OCTOBER, 1921.
The lowest or any Tender will not necessarily be accepted, and the Corporation will not consider any Tender which is incomplete, or which does not include the whole of the work covered by the Specification.
By Order,
W. J. BOARD,
Town Clerk.
Guildhall,
Nottingham,
13th September, 1921. S 44

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon on Friday, 7th October,

Tenders for the Supply of:—

CLASS A.
1. Dog Spikes.
2. Steel Material.
CLASS B.
1. Fencing Materials.
2. Steel Fish-bolts, Nuts and Washers.
3. Wrought Iron.
4. Galvanized Steel or Ironwork.
CLASS C.
1. Pig Iron.
Tenders must be made on forms, copies of which, with Specification, can be obtained at these Offices on payment as follows:—
For Class A 20/- each, for Class B 10/- each, and for Class C 5/- each (which will not be returned).
The Directors do not bind themselves to accept the lowest or any Tender.
S. G. S. YOUNG, Secretary.
Offices: The White Mansion, 91, Petty France, Westminster, S.W. 1.
12th September, 1921. S 39

APPOINTMENTS OPEN.

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The Committee Require the

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MAN with technical training WANTED for large manufacturing plant. State experience and salary required.—Address, CORRESPONDENT, WM. PORTEOUS & Co., Advertising Agents, Glasgow. R 954

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Blast Furnace Manager

WANTED for large modern Plant producing Basic Iron.—Address, stating age, experience, and salary required, S 46, Offices of ENGINEERING.

Works Manager Wanted, for

Hot and Cold Steel Rolling Mills in Staffordshire, to take charge of Works producing Hot Rolled Sheets, Strips, Flat and Special Sections, and Cold Rolled Strips and Sheets.
Applicants must have the necessary experience in the trade and be capable of controlling the labour and producing the output on the most economical basis consistent with quality. Address stating experience, age, giving references in confidence, stating when at liberty and salary required.—S 33, Offices of ENGINEERING.

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The position demands initiative, energy, and an exceptionally high degree of scientific and technical knowledge, and a wide practical experience.
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LIMITED of Hayes, Middlesex are increasing their Drawing Office Staff and have a number of VACANCIES for ENGINEERING DRAUGHTSMEN with previous Aircraft Experience.—Write stating age, particulars of experience and salary required to SECRETARY. S 34

Architectural Draughts-

MAN (Junior) REQUIRED with previous Drawing Office experience, knowledge of Building Construction and Surveying and Levelling.
Preference given to Ex-service men.
Write stating age, experience, salary required and enclosing recent testimonials, together with evidence of Military Service, if any, to THE OFFICER IN CHARGE OF WORKS, Naval Training Establishment, Shotley, near Ipswich. R 991

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The Metropolitan Asylums Board invite—

Applications for the following

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Candidates must not be less than 25 nor more than 35 years of age.
Application forms can be obtained from the undersigned on and after Wednesday, 14th September, 1921, and must be returned, accompanied by copies of testimonials, not later than TEN a.m., Saturday, 24th September, 1921.
Envelopes to be endorsed "Application for Draughtsman." Requests for forms made by post must be accompanied by stamped, addressed envelopes.
By Order,
DUNCOMBE MANN.
Office of the Board,
Embankment, E.C. 4. S 45

Wanted, First-Class

DRAUGHTSMAN for INDIA, with experience of Textile and General Machinery. Experience in jig and tool design an advantage.—Apply, by letter only, giving full particulars, A.C.C., 79, Grosvenor Place, London, S.W. 1. S 49

Draughtsman and Estimator

REQUIRED, to take charge of drawing office, by manufacturers of conveying and elevating machinery, coal handling plants, structural work, &c. Works near London.—Address, stating full particulars, S 70, Offices of ENGINEERING.

Die Castings. — First-Class

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THE ROTARY PIERCING MACHINE FOR STEEL AND COPPER BILLETS.

By C. E. DAVIES, A.M.I.Mech.E.

THE rotary billet-piercing machine is now very generally known to be a form of rolling mill for the production of hollow, weldless steel or copper tubes, from the solid billet, or ingot, by means of rolling the solid billet between inclined rolls, and is perhaps the most important invention, which has been adopted, during the last twenty or thirty years, in the manufacture of weldless tubes.

Invented in Germany, it is only comparatively recently that it has been in general use in this country, and the writer, who has been associated in the manufacture of these machines in England, has found very little information available, on the practice or theory of the process.

The action of inclined rolls in forming a hollow shell from a solid bar has been roughly described in many text-books on rolling mill practice, metallurgy &c., but little attempt has been made to elucidate the somewhat complicated theory, which explains the success of the rotary piercer.

In the course of a general study of the ordinary rolling process (of which rotary piercing is a special case) the writer has endeavoured to outline a satisfactory theory for the rotary piercer, but finding that a very exhaustive article on the subject had been published by *Stahl und Eisen* (September, 1919) it seemed best to prepare a free translation of the German article modifying the original, as deemed necessary to render the matter intelligible to British engineers, with possibly some notes on British practice with these machines. The following description and theory is directly obtained from the translation of the article referred to above, without alteration of consequence to the sense of the original, and interpolating only such explanatory paragraphs as were thought advisable to make the subject clear.

A short summary, with some remarks on the design and use of the rotary piercer in this country are added in conclusion.

The explanatory figures, Nos. 1 to 19, are copied from those illustrating the article in *Stahl und Eisen*.

CONCERNING THE PRODUCTION OF SEAMLESS TUBES, WITH SPECIAL REFERENCE TO THE MANNESMANN INCLINED ROLL PROCESS.

To the Brothers Mannesmann, of Remschied, is due the credit of having first discovered that it is possible to pierce solid round billets by rolling them between inclined rolls.

This discovery created a great stir in the technical world in the years 1888–1890; so much the more because the inventors then conceived the process to be capable of a more important application than was later found to be possible. Inclined rolls were already well known ten years earlier, but were only used for straightening and polishing round bars and tubes (and are still employed for this purpose in the modern reeler—C.E.D.).

Many difficulties presented themselves, at the start, in working this process, so that it had not the desired success, though well supported financially; the chief cause of failure was the fact that, according to the ideas of the inventor, finished tubes could be produced by the machine, but this idea had, eventually, to be entirely abandoned.

The fault was not exactly due to any defect in the design, which was not then fully developed, but to the great difficulty experienced in the production of a material of good homogeneous quality (absolutely necessary for the Mannesmann process) which would have sufficient cohesion of its particles. Laminated and "spilly" material is still a source of trouble even with the most modern type of piercing mill.

The rotary piercer is, to-day, employed only as a "roughing" mill, and with it a solid billet can be converted into a shell, 20 mm. to 30 mm. thick, having a weight equivalent to that of a tube 8 mm. to 10 mm. thickness of wall, up to 12 m. long, in one piece. For the production of finished tubes from 2½ mm. to 10 mm. or 11 mm. thick, finishing rolls are used; the "Pilger mill," another invention of the Mannesmann Brothers, is designed for this purpose, and will elongate and reduce the thickness of the thick shell produced by the piercer.

Referring to Fig. 1, supposing a cylinder A is supported in bearings allowing both rotation and axial motion, and a roll B, axially inclined to A, presses upon it; any rotation of B will be transmitted to A, which will at the same time be displaced endwise. If β is the angle between the axes of A and B, and V is the tangential velocity of B, the resulting tangential velocity of A is, V cos, β, and the velocity of movement axially is V sin β. The power available to produce this rotation and displacement endwise is dependant on the pressure between A and B.

If, on the other side of cylinder A, another roll similar to B is pressing, its axis also making an angle β with the axis of A, a more positive motion and rotation of the cylinder is obtained owing to the pressure being balanced (see Fig. 2). If now, the cylinder (or billet) A is fixed to a thrust bearing C, so that end motion is no longer possible, there will be a tendency, at the point of contact, between A and B, to carry forward the outer surface of the material, in the direction of the end motion mentioned previously.

This tendency to push forward the outer skin of the cylinder would in the case supposed, have only the effect of wearing away the surface at points of contact, but it is on this action that the principle of the rotary piercer is founded. Fig. 3 illustrates the process, as it actually operates in practice. The billet A is held back by a taper formed on the rolls, and the outer surface is pushed forward, this action is not confined to the surface, but extends inwards to the centre of the piece, the material, as will be explained more fully later being drawn out from the centre, in the form of a spiral towards the surface, and being at the same time pushed forward.

It appears that the earlier supposition, that it is necessary to employ a "plug" or piercing tool to hold back the core of the billet was incorrect, although this earlier opinion was, at first, accepted by the inventors and by Professor Reuleaux.

The hollow shell is first formed without the use of the piercing plug; this plug, as employed in the piercing mill, has only the object of bringing the shell to a uniform thickness, smoothing the bore, and really helps chiefly in the piercing of the last part of the length of the billet.

As mentioned above, the process calls for particularly homogeneous material; there must be cohesion between the individual fibres, so that the drag on the outer surface can be transmittted through the body of the material. This is all the more noticeable the thinner the wall of the shell. It is for this reason that the rotary piercer of the Mannesmann type is increasingly employed in the manufacture of copper tubes, even for the thinnest walls. (Copper shells 3 in. or 4 in. in diameter, with walls $\frac{5}{16}$ in. and $\frac{1}{4}$ in. thick, are regularly produced in this country, by piercers of this type.—C.E.D.)

(1) *The Theory of the Mannesmann Rotary Piercer.*—The rolls shown in Figs. 4, 5 and 6, are a very usual design for the Mannesmann piercer, and are suitable for piercing billets 80 mm. to 160 mm. diameter.

The greatest diameter of the roll is 360 mm. (14·2 in.), and the total length of the barrel is 500 mm. (19·7 in.); for dealing with still larger billets the rolls are made 450 mm. (17·7 in.) diameter and 550 mm. to 650 mm. (21·7 in. to 25·6 in.) long. From the greatest diameter D (Figs. 7 and 8, page 398), the roll barrel tapers away to the right, for the length L, making an angle of taper α. The camber of the rolls is of the greatest importance to the piercing process, and the theoretical considerations are chiefly concerned with this point. The tangent of the angle of taper α may be from $\frac{1}{8}$ to $\frac{1}{16}$.

A second point of special importance is the angle of inclination of the roll axes; each roll lies at a similar angle β above and below the horizontal (usually about 5 deg.). Thus, the centre lines of the rolls in their projection on to the vertical plane, are inclined to one another at 2 β (about 10 deg.), and intersect at the middle point of the roll length; this point, which coincides with the projection of the intersection of the axes on to a vertical plane midway between the rolls, is called the central

Fig. 1. THE ACTION OF AN INCLINED ROLL.

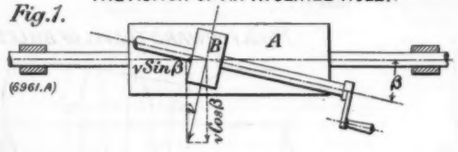
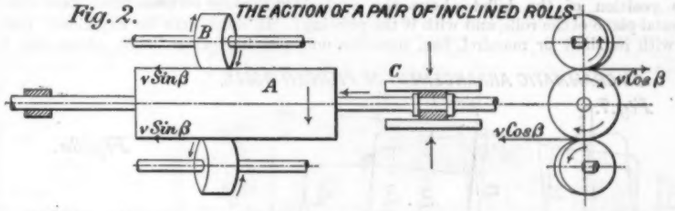


Fig. 2. THE ACTION OF A PAIR OF INCLINED ROLLS.



THE DEVELOPEMENT OF A HOLLOW SHELL BY THE ACTION OF INCLINED ROLLS.

Fig. 3.

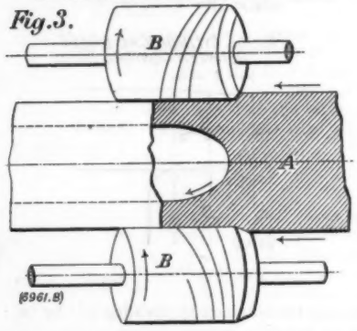
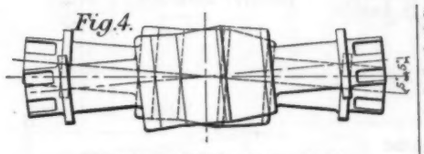


Fig. 4.



Maximum Billet Dia. 160 m/m.
Minimum ..... 80 m/m.

Fig. 5.

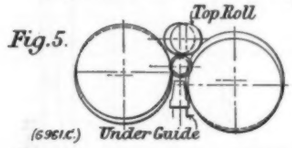
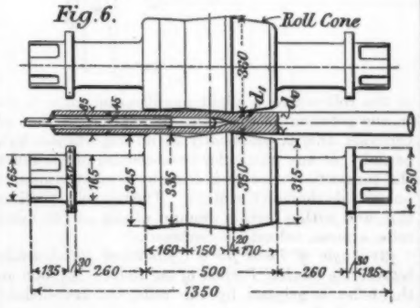


Fig. 6.



point M. All dimensions are taken from this point and the horizontal plane of the point M is the chief reference plane of the machine.

This angle of the rolls causes the automatic feeding in of the billet, but the path of the billet through the rolls is not at the level of the central point M, but at a distance h (about 40 mm.) above it. (See Fig. 8.) This being so, the billet would be forced out towards the top of the rolls, were it not prevented from doing so by a third roll, this top roll has to take a part of the roll pressure, and forms a top guide, or "gauging" roll for the billet during the piercing operation.

A bottom guide bar is not necessary, but is frequently fitted. No special advantage is gained from the position of the billet centre line being above the central horizontal plane of the rolls, in fact, for this reason the low-lying ends of the rolls must be swung round towards the billet, so that the centre lines of the rolls are inclined to one another in every plane.

The position of the billet above the central horizontal plane of the rolls, and with it the piercing plug, with its shaft or mandrel, has, however, one advantage, in that it gives a greater clearance where these pass the roll bearing caps, and consequently it is possible to provide for ample strength in the bearing design.

Both rolls thus revolve in the same direction and at the same speed; the billet is therefore driven round in the opposite direction, the upper surface of the billet turning from the roll with its high-lying end (looking at the entry side) towards the roll with its low-lying end at this side of the mill. The billet will then be drawn in automatically between the rolls. The top roll runs freely and is, of course, driven by the billet at the same peripheral speed as the main rolls.

(2) *The Tangential Velocity of the Taper Surface of the Rolls and Billet.*—If a section be taken at any given point through the conical ends of the rolls at right angles to the axis, when the diameter of roll is Dx, the tangential velocity will be $Vx = Dx\,\pi\,n/60$ metres per second (n being the revolutions per minute of the rolls). If, at the corresponding section, the diameter of the billet is $d\,x$, and its speed $n\,x$ (the diameter of that part of the billet between the conical portion of the rolls, decreasing from d_0 to d_1, as the roll diameter increases from D_0 to D), it is obvious that the speed of rotation of the billet will increase very rapidly from n_0 to n_1.

This variable speed $n\,x$ will be expressed by the equation:

$$nx = Dx/dx \cos\beta\, n \quad . \quad . \quad . \quad (1)$$
$$dx\,\pi\,nx/60 = Vx \cos\beta.$$

(See Fig. 8A.) Assuming that the longitudinal travel of the billet is equal to the horizontal component (V sin β), at the circumference of the rolls, the travel per revolution must be:

$$sx = dx\,\pi \tan\beta. \quad . \quad . \quad . \quad (2)$$

(See Figs. 8A and 9.)

The feed forward per revolution of the billet between the rolls determines the "pitch" of the imaginary spiral, described on the conical surface of that part of the billet between the rolls.

With the mill designed for a particular angle of the rolls β, the pitch of the helix, or feed per revolution, is proportional to the diameter.

That is:

with $\beta = 4°$, or $\tan\beta = 0{\cdot}07$, $sx = 0{\cdot}22\,dx$.
with $\beta = 5°$, or $\tan\beta = 0{\cdot}0875$, $sx = 0{\cdot}275\,dx$.

The billet, therefore, travels forward, as though screwed in between the rolls, with a tapered thread, this screw reforming itself continuously.

Now as soon as the billet travels forward sufficiently to meet the piercing plug, the resulting increased resistance to forward movement causes the feed per revolution to be reduced, the speed of rotation remaining constant; the helix has then a reduced pitch and, moreover, when the end of the billet is passing between the rolls, the formation of the hole becomes much more difficult.

It must here be explained, that, owing to the piercing centre being above the horizontal plane of the roll centre, a slight modification takes place in the rotation of the billet in relation to that of the rolls, this is practically of no importance, but, actually, at any particular cross-section of the billet the tangential velocity is less, by a small amount, on one side than on the other. The top roll equalises this, and with a certain amount of slip on the main rolls, a mean velocity is obtained.

(3) *Angle of Twist for a Cylindrical Billet, while between the Conical Portion of the Rolls.*—As soon as the billet is gripped by the rolls, its revolutions per minute become:

$$n_0 = D_0/d_0 \cos\beta\, n.$$

These revolutions increase regularly until the smallest diameter of the billet d_1, and the corresponding largest diameter of the rolls D is reached.

$$n_1 = D/d_1 \cos\beta\, n.$$

The revolutions per second increase in proportion to $n_0/60$ to $n_1/60$. In each second, therefore, there is an increase in the speed of rotation at the smallest cross-section of the billet

$$\frac{n_1 - n_0}{60}.$$

This increase can be expressed as an angle of "twist" in degrees.

$$\frac{n_1 - n_0}{60}\,360.$$

The forward travel of the billet requires time, t seconds from the start, at its original diameter, to the reaching of the smallest cross-section, and a definite value can be given to this angle of twist per second:

$$\phi = \frac{n_1 - n_0}{60} \times 360\,t \quad . \quad . \quad . \quad . \quad (3)$$

So long as the time t for the change in diameter of the billet from d_0 to d_1 remains constant, so long will the angle of twist ϕ maintain this definite value.

The magnitude of the angle ϕ may be taken to be a measure of the formation of the hollow in the billet, and for a definite angle there will be a corresponding definite ratio of the inside diameter to the smallest diameter of the billet d_1. This being so, it is necessary to determine more exactly the value of ϕ from the roll and billet dimensions. The length l of the billet taper is:

$$l = D - D_0/2 \tan a = d_0 - d_1/2 \tan a \quad . \quad (4)$$

The longitudinal velocity of the billet, or the forward travel per second, is at any given point:

$$c = Vx \sin\beta = Dx\,\pi\,n/60 \sin\beta.$$

This velocity increases between the limits C_0 and C_1.

$$c_0 = D_0\,\pi\,n/60 \sin\beta.$$
$$c_1 = D\,\pi\,n/60 \sin\beta.$$

the mean velocity being, therefore, $\frac{C_0 + C_1}{2}$ that is:

$$c = \frac{D + D_0}{2}\,\pi\,\frac{n}{60} \sin\beta. \quad . \quad . \quad (5)$$

The time t is obtained by dividing (iv) by (v):

$$t = \frac{l}{c} = \frac{d_0 - d_1}{D + D_0} \cdot \frac{1}{\pi\,n/60 \sin\beta \tan a} \quad . \quad (6)$$

From the equation given, for n_0 and n_1, we can at once write:

$$n_1 - n_0/60 = (D/d_1 - D_0/d_0)\,n/60 \cos\beta \quad . \quad (7)$$

and by substituting the values of (vi) and (vii), in equation (3), we obtain the value for the angle of twist—

$$\phi = \left(\frac{D}{d_1} - \frac{D_0}{d_0}\right)\left(\frac{d_0 - d_1}{D + D_0}\right) \cdot \frac{360}{\pi \tan\beta \tan a} \quad (8)$$

or as

$$\phi = \frac{D\left(\frac{d_0 - d_1}{d_1}\right) - D_0\left(\frac{d_0 - d_1}{d_0}\right)}{D + D_0} \cdot \frac{360}{\pi \tan\beta \tan a}$$

In this equation is expressed the influence, which is exercised (in any individual case under consideration), by the angle of torsion on the power of transforming the solid billet into a hollow shell.

The second factor, including the angles a and β, is constant for any given machine, and for the Mannesmann mill with rolls 360 mm. diameter β is generally 5 deg., on the other hand the angle a is very variable.

With $a = 4$ deg., the second factor becomes $= 360/0{\cdot}01925 = 18{,}700$, and when $a = 7$ deg., it is $360/0{\cdot}03377 = 10{,}700$.

The angle of twist will vary very considerably with these two values.

Let the first factor in equation (8) = E. That is:

$$E = \frac{D\left(\frac{d_0 - d_1}{d_1}\right) - D_0\left(\frac{d_0 - d_1}{d_0}\right)}{D + D_0}$$

$D = 360$ mm.; $d_0 = 80$ to 160 mm.; $D - D_0 = d_0 - d_1$.

From this D_0 is determined. (See Table I.)

From the figures given in Table I, it will be seen

DIAGRAMMATIC ARRANGEMENT OF PIERCER ROLLS.

Fig. 7.

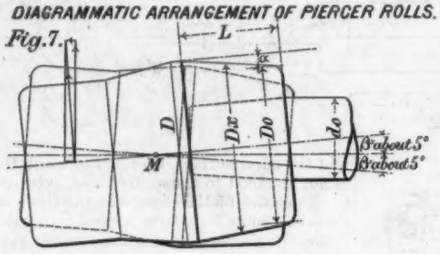


Fig. 8.

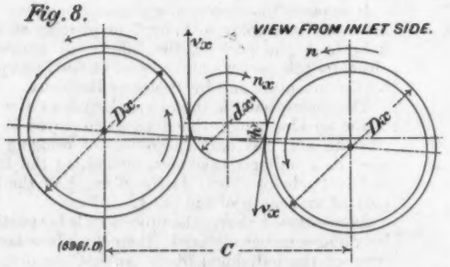


Fig. 8a. VELOCITY DIAGRAM.

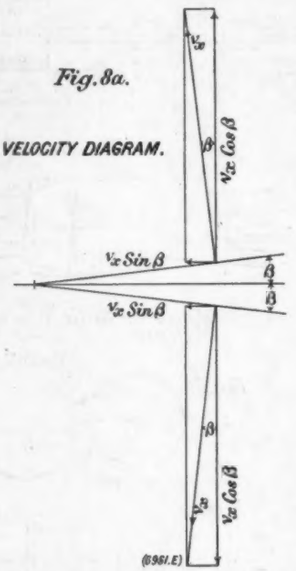


Fig. 9. FORWARD TRAVEL OF BILLET.

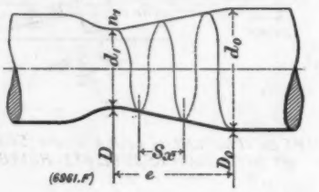
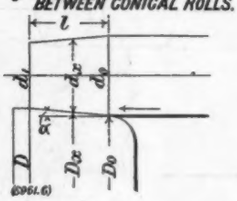


Fig. 9a. CYLINDRICAL BILLET BETWEEN CONICAL ROLLS.



that in bringing the rolls closer together, the value of E, and consequently the angle of torsion ϕ, increases very rapidly; if the value, $d_0 - d_1$, is trebled, then the value of E is seen to be increased tenfold. Approximately it may be said that the torsion angle ϕ, and consequently the "piercing effect," increases as the square of the reduction in diameter of the billet, effected by the rolls, *e.g.*, as $(d_0 - d_1)^2$.

It may be noted that in setting the rolls, they should be adjusted so that a hole is formed large enough to allow the shell to be pushed easily over the "plug," and at the same time to produce a sufficiently smooth inner surface. If the plug offers too great a resistance to the forward travel of the billet, the rolls must be set closer together, so that the hole formed will become larger, and the resistance reduced.

TABLE I.—*Roll Setting and Torsion Angle.*

$\frac{d_0 - d_1}{d_0}$	0·05	0·10	0·15
$d_0 - d_1$	4	8	12
d_0	80	80	80
E	0·0016	0·00674	0·0160
$d_0 - d_1$	8	16	24
d_0	160	160	160
E	0·00189	0·00796	0·01887

The development of equation (8) is based on the assumption that the billet passes freely between the rolls, but if this is not the case and the piercing plug offers considerable resistance, then the velocity may easily be reduced 50 per cent., and the time taken be twice as long as in the case of free passage. The value of ϕ for the torsion angle should not be changed for this reason.

[The exact meaning of the original German is not very clear on this point. Actually if, owing to the resistance of the plug, the feed forward per second of the billet is reduced 50 per cent., and assuming that the rotary speed of the billet is unchanged, the torsion angle would be doubled. For by equation (3):

$$\phi = \frac{n_1 \times n_0}{60} \times 360\, t.$$

On the other hand, by equation (8), based on the assumption of free passage, ϕ would not be altered, as the factors of speed and time are eliminated in this expression for the value of the torsion angle.

It is stated in the original that the value for ϕ as obtained by equation (8) is unchanged; this value, if put in would appear to be half the actual value of this angle.—C.E.D.] *

This change, from free passage, is noticeable when the end of the billet is passing between the rolls; then, there is no longer any hole-forming effect, and resistance of the plug reaches a very high value. Herein lies the difficult part of the piercing process, and there is a very considerable increase in the power required at the end of the operation.

(*To be continued.*)

LARGE ELECTRIC UNITS.*

By STANLEY PARKER SMITH, D.Sc., Assistant Professor in Electrical Engineering, at the City and Guilds (Engineering) College.

Introductory Note on Prime Movers.—The development of prime movers has largely influenced the development of electric generators, and conversely. Transmission problems and the growing demand for electric energy have given a great impetus to alternating-current machinery.

Steam Turbines have now reached a high stage of development and can meet practically all needs as regards output and speed. Units of 25,000 kw. to 35,000 kw. are probably large enough to give good all-round economy without involving too much capital expenditure in spare plant and without causing too much disturbance in the event of failures. One of the most interesting developments of recent years has been the Ljungström steam turbine, in which the electric unit is split into halves. By making these halves rotate in opposite directions, the relative blade speed in the turbine is made equal to twice the actual running speed, resulting in a very small turbine, low steam consumption, and the possibility of much larger units at 3,000 r.p.m. than with ordinary turbines, because each generator gives only half the output of the unit. The two stator windings are connected permanently in parallel and the two rotor windings in series. The set is started with the exciter circuit closed and the two alternators synchronise automatically at about half speed. The whole set can be mounted on the condenser.

A Ljungström set by the Brush Electrical Engineering Company is shown in Fig. 1.

Large Internal-Combustion Engines have been widely developed on the Continent. Gas engines are now installed in most iron and steel works to utilise blast-furnace gas. The exhaust gas from the engines can be further utilised by using it in gas-fired boilers, after which it can be used for heating the feed water—the extra power thus obtained from the steam turbines may amount to one-eighth or more of the total. Recent developments are illustrated by greater reliability, simplification of valve gears, use of compressed air for starting, &c. Flywheels may be necessary for reducing cyclic irregularities, but may be dispensed with in alternators driven by twin tandem engines. Regarding 2,000 h.p. per cylinder as the present limiting output, such a set could give 8,000 h.p. An idea of the outputs and speeds obtainable with gas engines is obtained from the following figures for tandem engines:—

Cockerill: 1,000 h.p. at 115 r.p.m., to 3,600 h.p. at 94 r.p.m.
M.A.N., 715 h.p. at 167 r.p.m., to 3,500 h.p. at 94 r.p.m.

Twin-tandem (four-cylinder) engines give about twice the above powers. These figures may be compared with the following figures for Diesel engines with one to six cylinders:—

Sulzer: 20 h.p. at 260 r.p.m., to 4,000 h.p. at 125 r.p.m.
M.A.N.: 85 h.p. at 200 r.p.m., to 1,500 h.p. at 150 r.p.m.

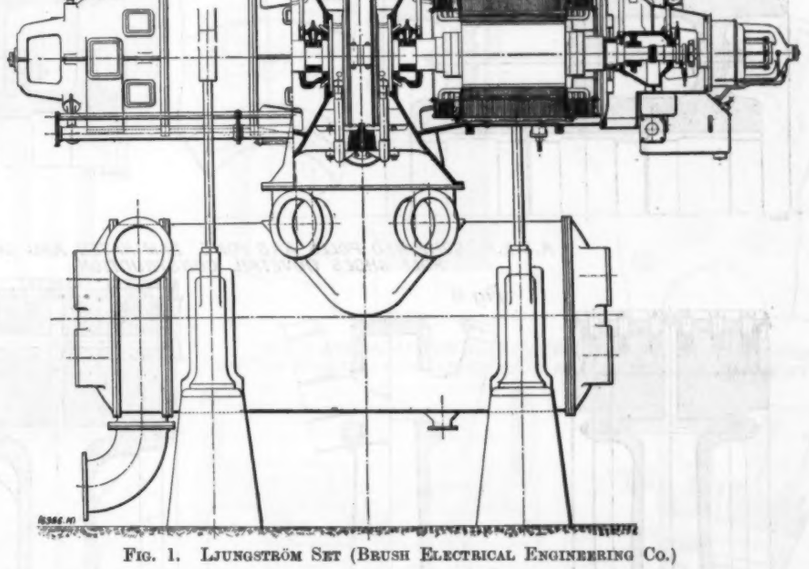


FIG. 1. LJUNGSTRÖM SET (BRUSH ELECTRICAL ENGINEERING CO.)

Water Turbines.—In no other direction has development been greater than in hydroelectric work. The design of both impulse and reaction turbines has been greatly improved as a result of experience. Heads of 3,000 ft. and units of 20,000 h.p. are becoming quite common. So long as coal was relatively cheap and easily obtained, development was rather slow, but the coal famine of recent years proved sufficiently powerful to overcome the adverse financial conditions. In many countries definite policies are being carried out in connection with water-power schemes—*e.g.*, to secure continuity of supply, the Alpine stations in Italy are linked up with the Apennine stations; while in Switzerland, high-head stations with storage capacity are linked up with low-head, river stations working on constant load. In Germany, power is obtained at the weirs of canalised rivers. Railways are being worked electrically by power obtained from hydraulic stations in Sweden, Switzerland, Austria and Italy. The greatest difficulty in the construction of alternators for this work is the need for safeguarding them against overspeeds, which vary from 80 per cent. to well over 100 per cent., according to the type of turbine, &c.

PRODUCTION OF ALTERNATING-CURRENT ENERGY.

1. TURBO-ALTERNATORS.

Rotors.—The difficulties of construction, now well understood, have increased with increasing outputs. Three thousand revolutions per minute has become almost the standard speed for 50-cycle machines, and outputs up to 20,000 k.v.a. per unit are now practicable at this speed. This entails peripheral speeds up to, or even beyond, 25,000 ft. per minute. Despite the difficulties in obtaining large forgings weighing 20 tons to 25 tons in their finished condition, the solid rotor seems to be generally preferred to any form of built-up construction. As a result, dynamo makers both at home and abroad are insisting on more rigorous guarantees from steel makers, and a hole has generally to be bored or trepanned through the shaft to enable the interior of the forging to be examined and to provide test-pieces. The provision of efficient ventilation channels becomes very difficult in large sizes, and there is a marked tendency to rely exclusively on surface cooling, safety being ensured by non-combustible insulation. Water-cooled rotors are built, but such cooling may become superfluous if the simpler method proves satisfactory.

Despite mechanical weaknesses, the built-up rotor enables all parts to be thoroughly examined during construction and simplifies the provision of ventilation ducts. For large four-pole rotors, weighing 35 tons to 45 tons, some form of built-up construction appears to be necessary. Among the special constructions may be mentioned the parallel-slot rotor, and the salient-pole rotor. An interesting example of the latter is the arrangement by Ganz, in which grub screws are made to secure a solid pole-shoe and a sleeve which carries the winding (see Fig. 2). In large machines, particularly of the four-pole type, the rotor end-balls are often troublesome to design.

Illustrations of various types of rotors are given in the accompanying figures.

Stators.—Ventilation problems are here accentuated by the greater losses, and particular care has to be taken to keep down additional losses, especially in the embedded copper. For large sizes, neither simple axial nor simple radial ventilation is alone sufficient, but the air must be made to flow in some preordained manner, by some suitable arrangement. The manufacturer's difficulties in this country are often enhanced by having to build the stator on site. Water cooling is also being attempted to assist stator cooling. Station engineers are not yet wholly satisfied with the methods adopted for cleansing the cooling air—the method of circulating the cooling air through a refrigerator is being tried in several places. In the Schneider water-cooled stator, the water is first passed through the refrigerator used for cooling the circulating air. After absorbing heat from the air and from the machine, the water is then used to heat the feed water.

The end windings call for special consideration, and the state of the art is now such that turbo-alternators can safely withstand sudden short-circuit conditions, though in low-frequency systems an external reactance coil is sometimes considered a desirable additional safeguard. Both single- and double-layer stator windings are widely used, and with the latter arrangement, the coil-span is often adjusted to suit design conditions. Automatic voltage regulation is becoming universal, the popular methods being those which act on the exciting current of the exciter.

2. WATER WHEEL ALTERNATORS.

The main difficulty in all water-wheel-driven generators arises from the runaway speed, which may be considerably over 100 per cent. above the normal speed. Five diagrams have been prepared from the information supplied by the several firms, and show the great variety of methods used for securing the poles and windings. These are given in Figs. 2 to 18, on pages 400 and 401. Figs. 19 and 20, page 402, show a combination construction by the Oerlikon and by the S.A.C.M., and Fig. 21, page 403, the Niagara 32,500-k.v.a. alternator by the Allis-Chalmers Company. As in turbo-alternators, the stator winding is usually well braced to prevent accidents in the case of sudden short circuit.

Most modern types of water-wheel alternators are entirely enclosed to reduce windage loss and noise, and to protect the machine against eventual leaks. Large flywheel effect is generally important, and the water-

* Paper read before Section G of the British Association at Edinburgh, September 13, 1921.

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GANZ. TWO-PART ROTOR WITH CIRCULAR POLES SHOE-SLEEVE HELD BY LONG GRUBSCREWS

Fig. 2.

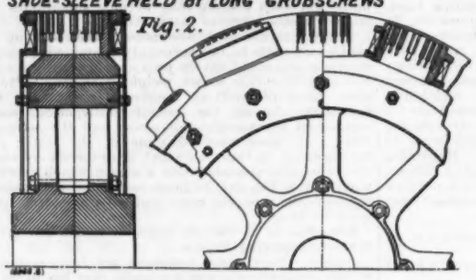


Fig. 3. OERLIKON AND S.A.C.M BELFORT (COMB TYPE) LAMINATED POLES INTERLEAVED WITH STEEL PLATES KEYED TO YOKE RINGS

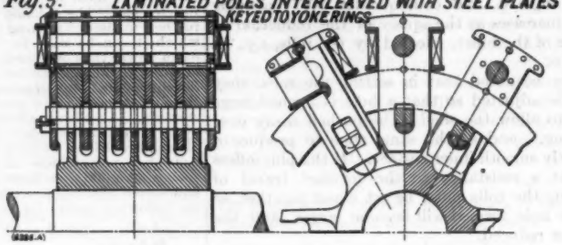
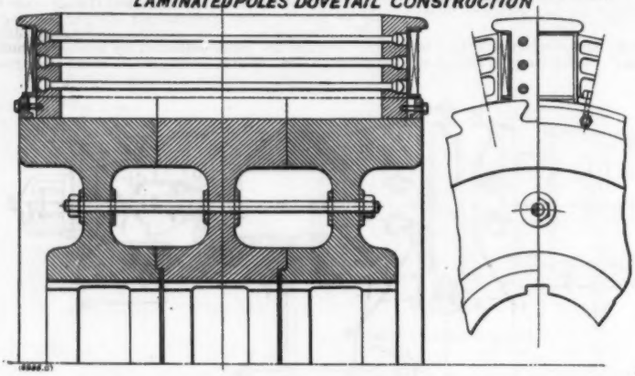
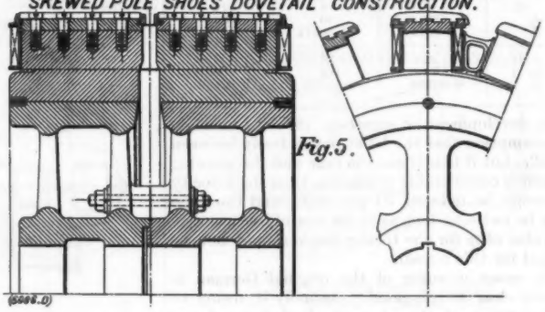


Fig. 4. ENGLISH ELECTRIC (DICK KERR) COMBINED YOKE AND SPIDER, LAMINATED POLES DOVETAIL CONSTRUCTION



A.S.E.A. COMBINED POLES AND YOKE, LAMINATED AND SKEWED POLE SHOES DOVETAIL CONSTRUCTION.

Fig. 5.



A.S.E.A. COMBINED POLES AND YOKE, LAMINATED AND SKEWED POLE SHOES DOVETAIL CONSTRUCTION.

Fig. 6

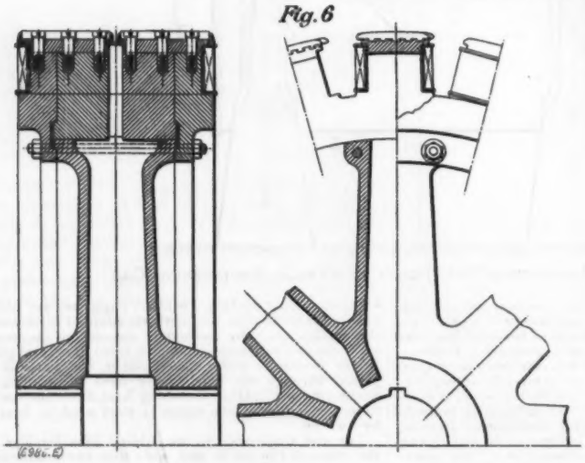
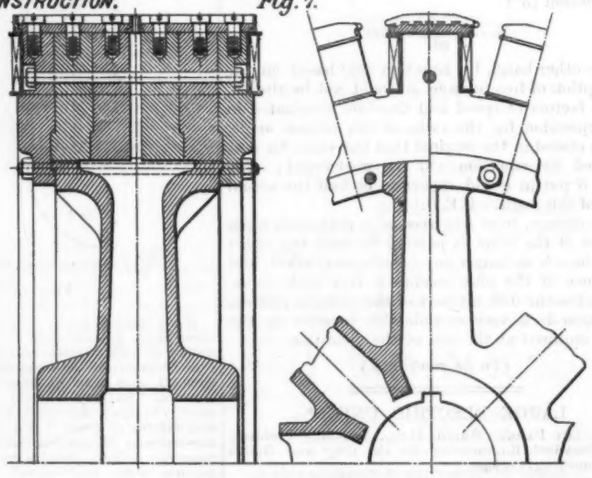
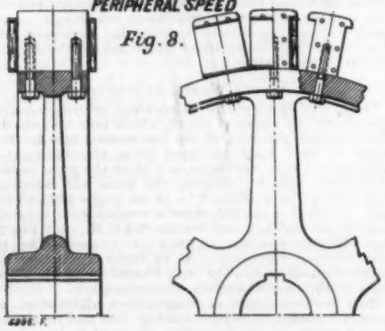


Fig. 7.



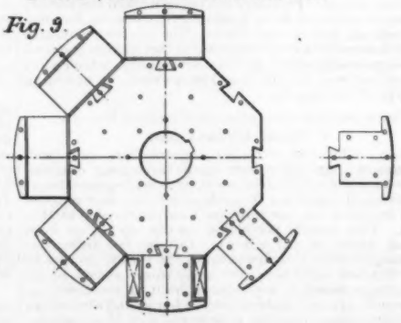
WESTINGHOUSE U.S.A. BOLTED ON POLES, LOW PERIPHERAL SPEED

Fig. 8.



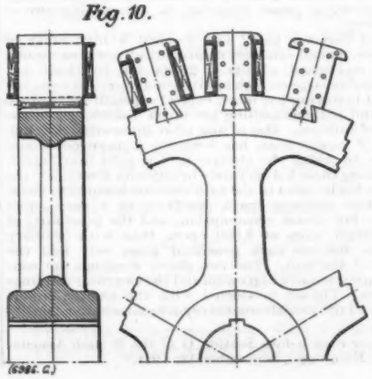
WESTINGHOUSE U.S.A. LAMINATED POLES & ROTOR DOVETAIL CONSTRUCTION

Fig. 9.



WESTINGHOUSE U.S.A. LAMINATED POLES DOVETAIL CONSTRUCTION

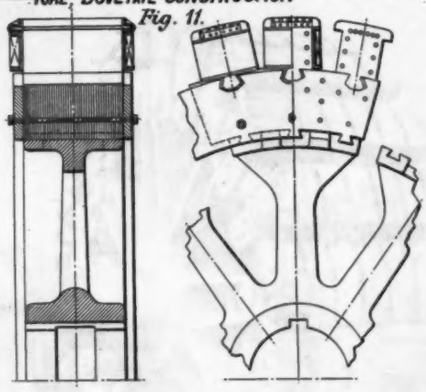
Fig. 10.



LARGE ELECTRIC UNITS.

WESTINGHOUSE U.S.A. LAMINATED POLES & YOKE, DOVETAIL CONSTRUCTION

Fig. 11.



A.S.E.A. COMBINED POLES AND YOKE WITH BOLTED ON POLE SHOES

Fig. 12.

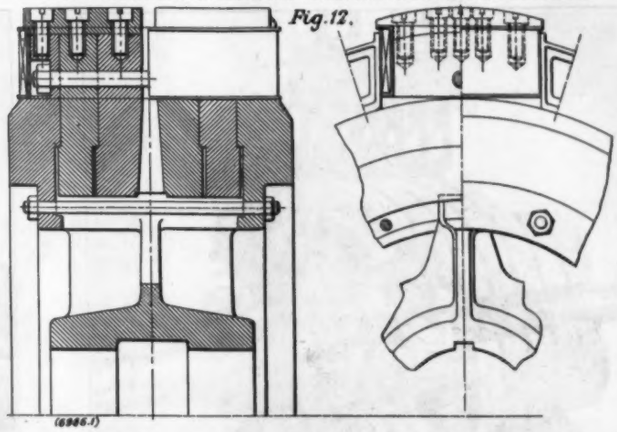


Fig. 13. A.S.E.A. BOLTED ON POLES.

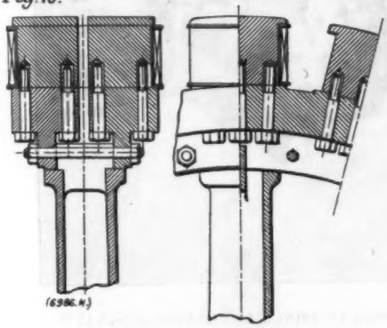


Fig. 14. A.S.E.A BOLTED ON POLES, LAMINATED AND SKEWED POLE SHOES DOVETAIL CONSTRUCTION

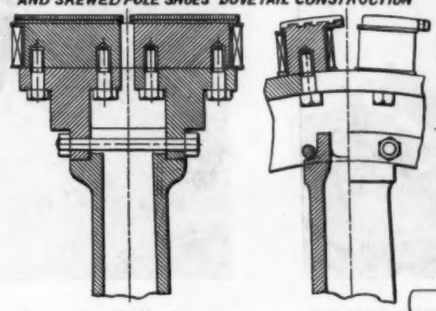
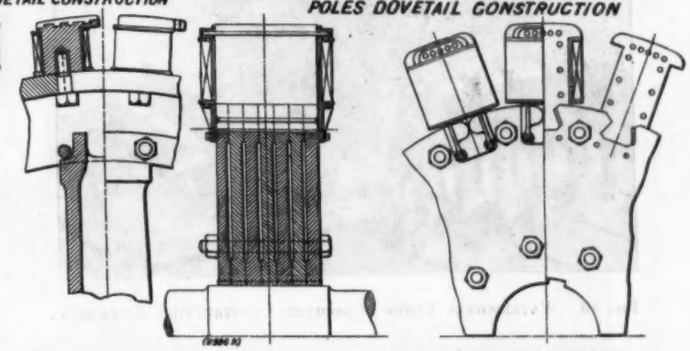
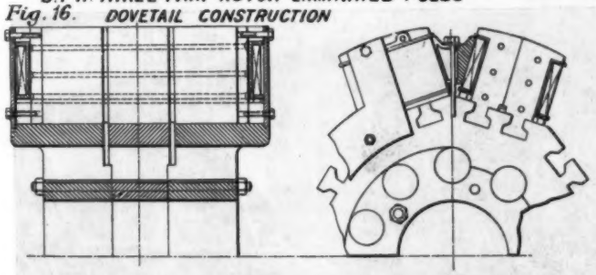


Fig. 15. WESTINGHOUSE U.S.A. PLATE ROTOR LAMINATED POLES DOVETAIL CONSTRUCTION



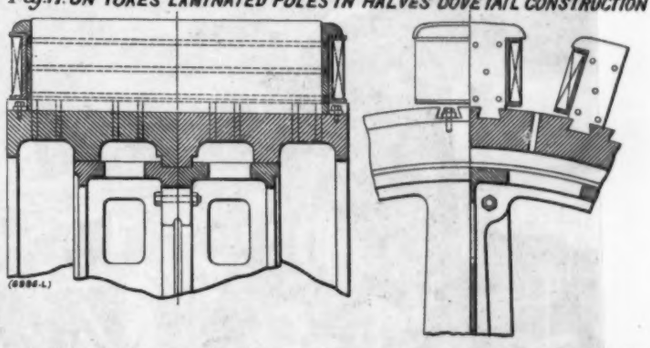
B.T.H. THREE-PART ROTOR LAMINATED POLES

Fig. 16. DOVETAIL CONSTRUCTION



ALLIS-CHALMERS (FOR NIAGARA) TWO PART ROTOR WITH SHRUNK

Fig. 17. ON YOKES LAMINATED POLES IN HALVES DOVETAIL CONSTRUCTION



G.E.C. THREE-PART YOKE LAMINATED POLES DOVETAIL CONSTRUCTION

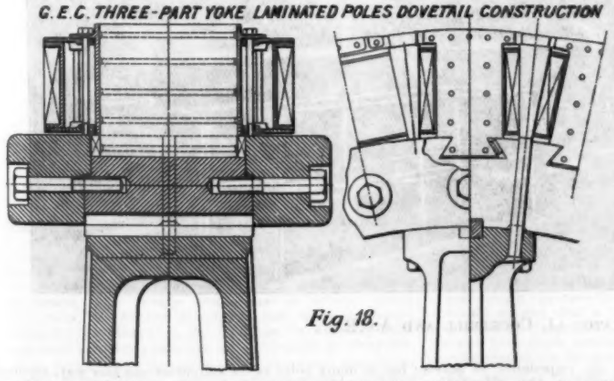


Fig. 18.

turbine manufacturer is generally anxious to have the necessary flywheel effect embodied in the rotor of the alternator, so as to dispense with a separate flywheel—a condition not always easily fulfilled by the dynamo builder.

A few days ago, the author saw two further interesting modes of construction—a robust construction by B.B.C. in which the pole cores were screwed into sleeves protruding from the yoke, and an Oerlikon construction in which the pole laminations were inserted between solid projections from the yoke and held by two large pins.

3. Slow-Speed Alternators.

These machines have become important again (after their suppression by the steam turbine) owing to the development of the internal-combustion engine and the adoption of reduction gearing. The large flywheel effect needed to obtain steady running with gas and oil engines often entails an "outer-pole" type of construction.

An illustration of a gas engine built by the Société Anonyme John Cockerell driving a 2,200-k.v.a., 2,000-volt generator, with 64 poles running at 94 r.p.m. built by the Charleroi Co. is shown in Fig. 22 on page 402.

Production of Continuous-Current Energy.

The following alternative methods for producing continuous-current energy will be considered:—

1. Direct-driven, slow-speed generators.
2. Slow-speed generators with reduction gearing.
3. Rotary and motor converters.
4. Mercury rectifiers.

The continuous-current turbo-generator may be regarded as dead. After being developed successfully at enormous cost, it has been ousted by more suitable apparatus.

The direct-driven continuous-current generator owes its extension of life largely to the development of the internal-combustion engine.

Probably the sternest competitors at the moment are the slow-speed generators driven by steam turbines through reduction gearing, and the combination of turbo-alternators with rotary converters. For large powers, the latter are probably cheaper and the more economical; but for small powers, the geared generator appears to many to be the ideal arrangement. Gearing has now been brought to a high pitch of efficiency and reliability, and permits the turbine to be run at a speed consistent with low steam consumption, and a generator which is economical both in cost and working.

Mercury rectifiers have only lately come on to the market, and it remains to be seen what influence these will have, particularly when their cost of manufacture is reduced.

1 and 2. Continuous Current Generators.—These may be coupled to slow-speed engines (steam, gas or oil), or to water turbines, or to steam turbines through reduction gearing. Illustrations of continuous-current generators are given in Figs. 23 to 25. The first of these shows a double commutator armature of 1,000 kw., running at 94 r.p.m., constructed by the Société

LARGE ELECTRIC UNITS.

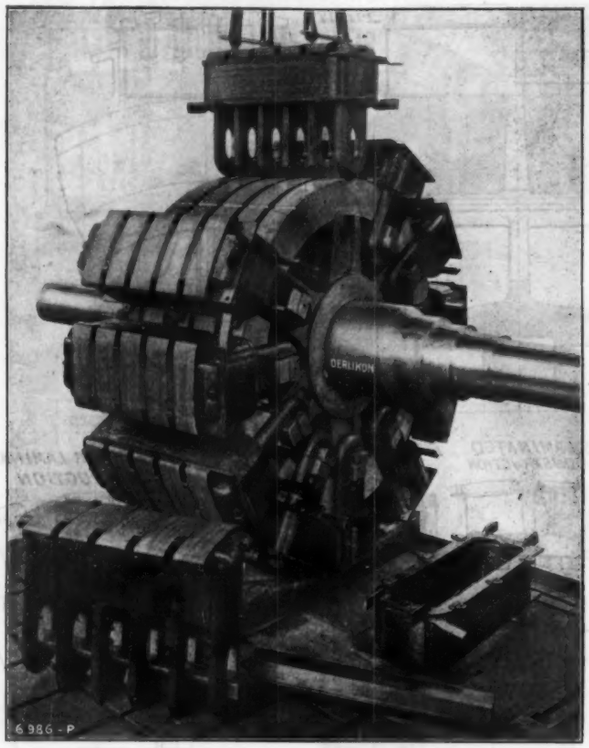


FIG. 19. WATERWHEEL ROTOR; COMBINED CONSTRUCTION (OERLIKON).

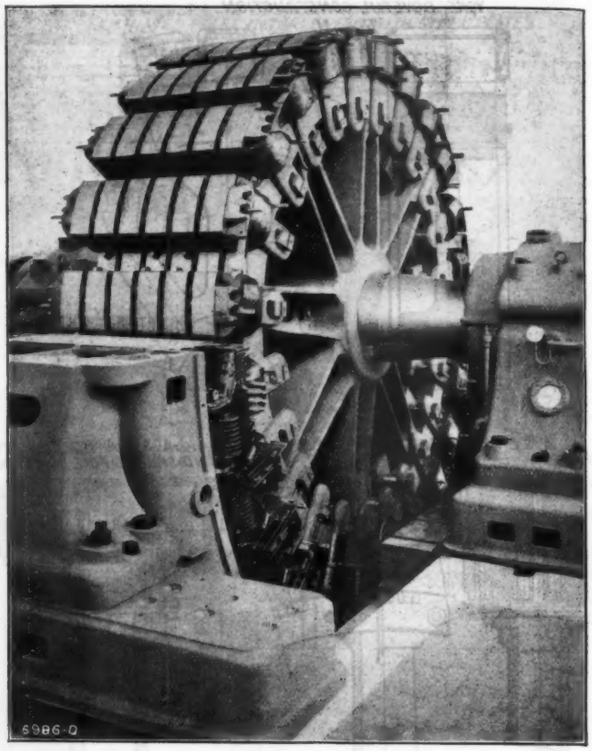


FIG. 20. WATERWHEEL ROTOR; COMBINED CONSTRUCTION (S.A.C.M.)

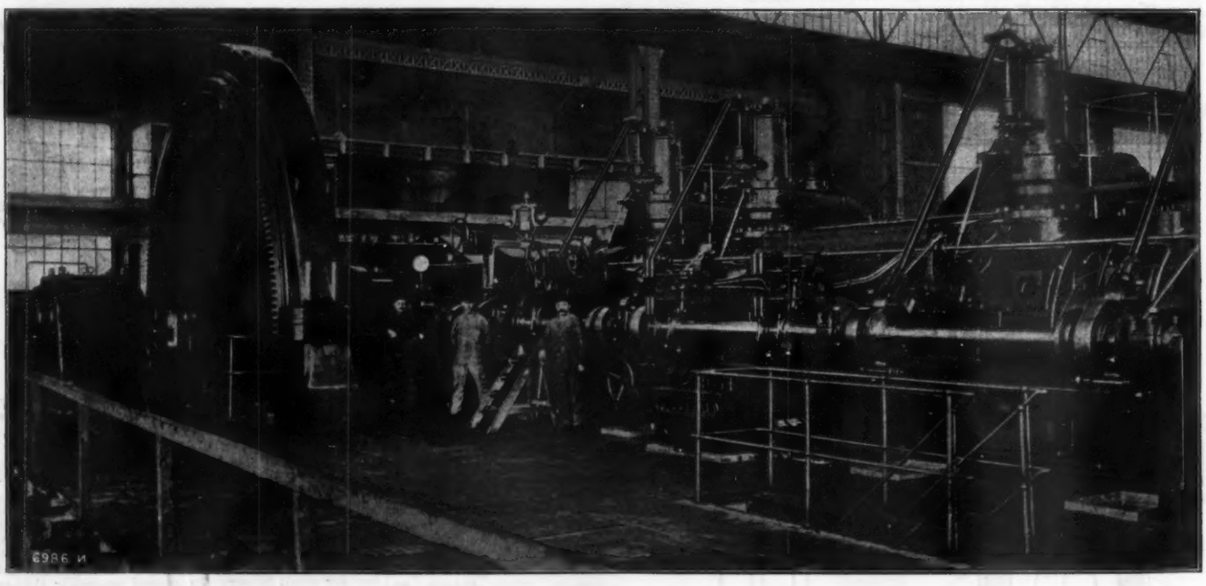


FIG. 22. GAS ENGINE DRIVEN ALTERNATOR (J. COCKERILL AND A.C.E.C.).

Alsacienne de Constructions Mécaniques à Belfort. It is used for three-wire distribution. Fig. 24 shows a water turbine-driven 3,000-kw. generator for 300 volts. It generates 10,000 amperes and runs at 300 r.p.m., and was built by the Allis-Chalmers Company. The third example, shown in Fig. 25, is a 3,000-kw., 375-volt, 300-r.p.m. set, constructed by the Oerlikon Company.

3. *Rotary and Motor Converters.*—Large converters started from the alternating-current side have usually a starting motor with two poles less than the converter. The starting motor is of the induction type and is commonly supplied with a solid cast-iron rotor for cheapness. In order to synchronise correctly automatically, it is usual to connect an impedance in series with the armature when applying the alternating pressure. One common way of doing this is to utilise the stator winding of the starting motor, by opening the neutral point and joining the phases in series with the slip-rings. Another method is to insert a choking coil in series with the slip rings. By these means the current is limited to a value which is insufficient to reverse the residual magnetism in the converter, which thus synchronises correctly. By increasing the induction motor field when the set approaches synchronous speed, Messrs. Mather and Platt have found that the converter will synchronize when the motor has as many poles as the converter—in this way, surging and sparking during the transition period are prevented.

Damping windings are universally used to prevent hunting, but experience has shown that the bars must be spaced so as not to produce fluctuations in the continuous pressure, because of the danger of telephonic interference. Various methods are in use for obtaining voltage regulation, including reactance control, booster control, induction-regulator control, and the much rarer methods such as the split-pole converter.

The difficulties connected with the design of rotary converters for 50 cycles and 60 cycles have been largely overcome, but with present limits it is difficult to build

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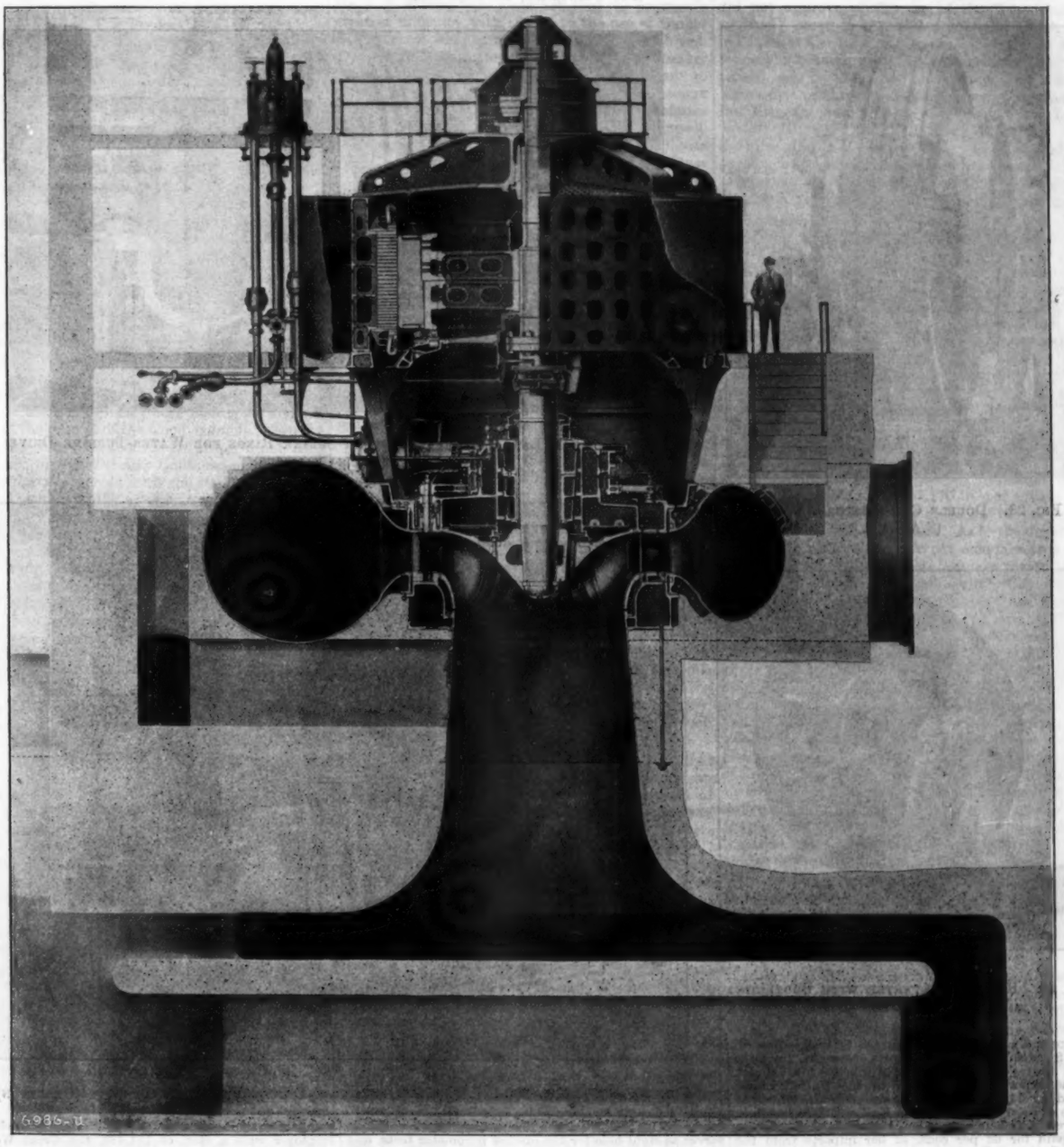


FIG. 21.—WATERWHEEL ALTERNATOR FOR NIAGARA 32,500 K.V.A. (ALLIS-CHALMERS CO.).

rotary converters for high pressures. Thus at 50 cycles, it is not easy to build a rotary converter for more than 1,000 volts. This matter is important for electric traction where it is desired to obtain 1,500 volts at 50 cycles. In this case it may become necessary to use either motor generators, two rotary converters in series, motor converters, or mercury rectifiers; but mention should be made of the fact that the Oerlikon Co. recently built a successful rotary converter for 1,500 volts at 50 cycles.

The motor converter owes its development mainly to Messrs. Bruce Peebles. Owing to the fact that pressures up to 11,000 volts can be applied direct to the stator winding of the induction machine, a transformer becomes unnecessary with these sets in many cases. The development and use of converting plant appears to be more general in Great Britain and in the United States of America than on the Continent of Europe. The protection against flashing-over used by the British Thomson-Houston Company is illustrated in Fig. 26.

4. *Mercury Rectifiers.*—After much experimental work, these have now been successfully developed by Messrs. Brown, Boveri and Co., and are now on the market in three sizes, namely, 300 amperes, 600 amperes and 1,000 amperes, at voltages up to 1,500. Rectifiers are also being built by German firms. Owing to the short time this apparatus has been in general use, it is too early to make a proper comparison with other types of converting machinery. From all accounts, however, it would appear that a very useful alternative method of converting alternating into continuous-current energy has now been made available. Slides shown at the meeting illustrated the Brown, Boveri rectifier.

The author's thanks are due to the several manufacturers for the valuable information they have supplied.*

* The following firms have kindly supplied information contained in the paper:—Allis-Chalmers Manufacturing Company (Allis-Chalmers), waterwheel alternators, c.c. generators. Ateliers de Constructions Electriques, Charlerol (A.C.E.C.), slow-speed alternators, c.c. generators. Bergmann Elektrizitäts Werke (Bergmann), turbo-alternators, slow-speed alternators, rotary converters. British Thomson-Houston Company (B.T.H.), turbo-alternators, waterwheel alternators, rotary converters. Brown, Boveri and Co. (Power Rectifiers) (B.C.C.), mercury rectifiers. Bruce Pebbles and Co. (Bruce Pebbles), motor converters. Brush Electrical Engineering Company (Brush), Ljungström steam turbine sets. English Electric Company (E.E.C.), turbo-alternators, waterwheel alternators, rotary converters. Ganz and Co. (Ganz), turbo-alternators, waterwheel alternators. General Electric Company (Witton), (G.E.C.), turbo-alternators, waterwheel alternators, rotary converters. Maschinenfabrik Oerlikon (Oerlikon), turbo-alternators, waterwheel alternators, slow-speed alternators, rotary converters, c.c. generators. Mather and Platt Company (Mather and Platt), slow-speed alternators, rotary converters, c.c. generators. Metropolitan-Vickers Electrical Company (Metrovick), turbo-alternators, waterwheel alternators, rotary converters. Parsons and Co. (Parsons), turbo-alternators. Schneider and Co. (Schneider), turbo-alternators, waterwheel alternators, rotary converters. Société Alsacienne de Constructions Mécaniques (S.A.C.M.), turbo-alternators, waterwheel alternators, c.c. generators. Svenska Turbinfabriks Aktiebolaget Ljungström (S.T.A.L.), Ljungström steam turbine sets. Swedish General Electric Company (A.S.E.A.), waterwheel alternators. Westinghouse Electric International Company (Am. West.), turbo-alternators, waterwheel alternators, rotary converters, c.c. generators. Valuable information on internal-combustion engines was also supplied by Messrs. Société Anonyme John Cockerill, Sulzer Frères, and by Maschinenfabrik Augsburg Nürnberg.

LARGE ELECTRIC UNITS.

(*For Description, see Page* 399.)

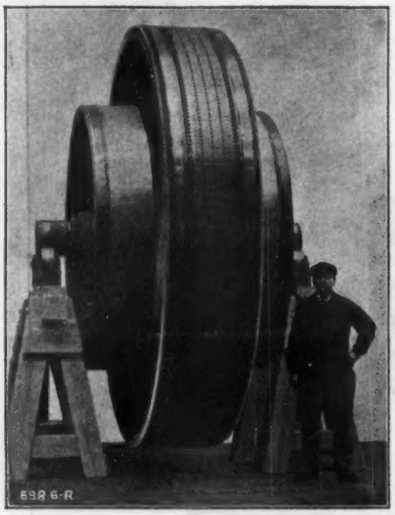


FIG. 23. DOUBLE COMMUTATOR ARMATURE (S.A.C.M.).

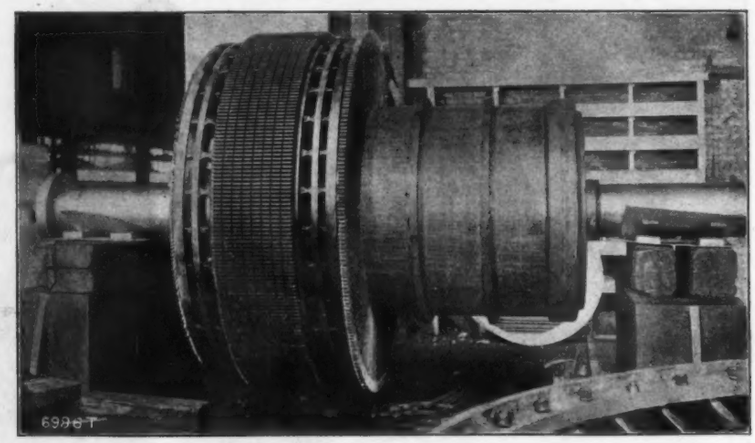


FIG. 24. LARGE COMMUTATOR WITH SHRINK RINGS FOR WATER-TURBINE DRIVE (ALLIS-CHALMERS).

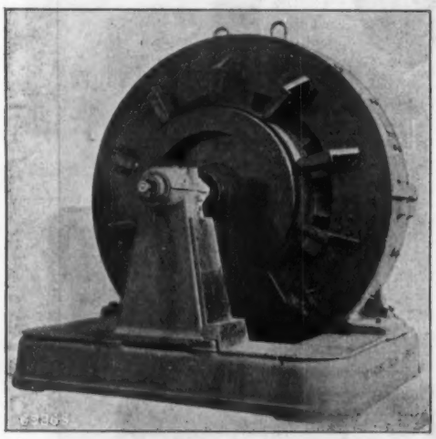


FIG. 26. ROTARY CONVERTER WITH PROTECTION AGAINST FLASH-OVER (B.T.H.).

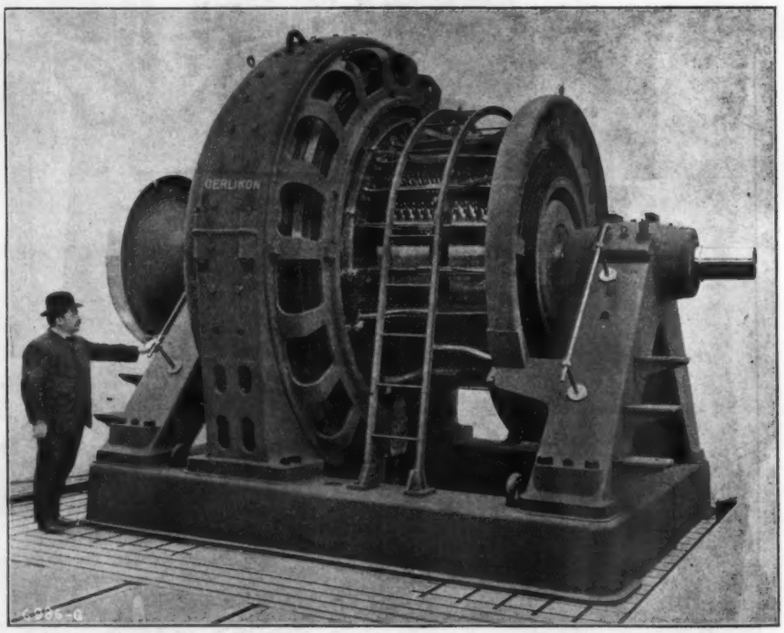


FIG. 25. 3,000-KW. 300-R.P.M. C.C. GENERATOR DRIVEN BY WATER TURBINE (OERLIKON).

SWEDISH TRADE WITH THE UNITED STATES.—According to Swedish experts, the imports of Sweden from the United States declined during April by 209,000 dol. and the exports from Sweden to the United States dropped by 35,000 dol. in the same period. Thus the balance of interchange with the United States has been improved in favour of Sweden, inasmuch as Sweden in April paid for 62 per cent. of her imports from the United States with export goods, compared with 59 per cent. during the preceding month.

HIGH-FREQUENCY CURRENT FURNACE.—The furnace for maintaining a "uniform high temperature throughout a large volume," which E. F. Northrup, of the Ajax Electrothermic Corporation, New Jersey, described in the July issue of the *Journal of Industrial and Engineering Chemistry*, is practically a jacketed graphite cylinder, 6 in. in diameter, 12 in. deep, made of Acheson graphite. The wall thickness is ¾ in.; the crucible is covered by a graphite plate of the same thickness, into the centre of which a vertical graphite tube, provided with a refractory sheath, is screwed, and extends upwards outside the furnace to a height of a foot or more. The graphite cylinder stands in a cylinder of micanite; the space between the two cylinders is packed with lampblack, which is considered the best thermal insulator at high temperatures. Outside the micanite is the water-cooled tubular copper coil for currents of from 60 amperes to 100 amperes at 10,000 cycles or 20,000 cycles per second, supplied by a 20-kw. converter. The coil is lagged outside with asbestos. Within an hour, the temperature throughout the crucible space is said to rise to 2,000 deg. C., and the temperature can be increased up to 2,500 deg. The vertical tube mentioned serves as sight-hole for the optical pyrometer tests, and also for applying pressure to the specimen which is placed in the crucible. The furnace is especially designed for testing refractory materials at high temperatures. Crushing tests are also mentioned, but there are no special arrangements for protecting the graphite crucible. A special claim is made as to temperature uniformity throughout the space of ½ cub. ft.

RAILWAY COMPANIES' STAFF.—A return recently issued shows that the number of employees of the railway companies of the United Kingdom, in March, 1921, amounted to 766,381. This return does not include staff still serving with the Colours, nor employees paid for time equivalent to less than three days in the week in which the figures were taken, nor staff employed by contractors on railway work. In 1913, the date of the last census, the total staff was 639,323. In the recent figure some 3,000 are included employed by clearing houses, not recorded in 1913. Excluding these the increase is one of 19·4 per cent., due mainly to the introduction of the 8-hour day. Detailed comparison is impossible because of re-grading and also for the fact that employees of the Mersey Docks and Harbour Board, Port of London Authority, and the Tyne Improvement Commission, are now excluded. As regards the larger companies, the London and North-Western is the largest employer with a staff of 101,483, the Great Western being next with 91,985. If the North-Western and Lancashire and Yorkshire be taken together the combine is by far the largest employer, having 146,871 on its books.

SUEZ CANAL TRAFFIC.—We recently recorded the official returns for the Suez Canal in 1919. Following close upon their publication come official statistics for 1920. These show the gross tonnage making use of the canal in that year to have amounted to 24,244,042, made up of 4,009 vessels. The preponderance, of course, was British, which country owned 61·7 per cent. of the shipping passing. Japan came next with 8·8 per cent., and Holland third with 8·2 per cent. Of the British vessels, 1,515 were merchant ships, 169 mail steamers and 279 warships and transports, with additional 146 vessels under Government charter. The passenger returns again reflect the large troop movements due to repatriation subsequent to the war. No less than 266,549 passengers of the total of 500,147 passing through the canal, were military. The average transit time was 16 hours 28 minutes in 1920, when 10 vessels drawing more than 29 ft. went through the canal. Two of the latter drew 30 ft., the authorised maximum, and one, H.M.S. Malaya, exceeded it, but made the passage by special sanction.

THE BRITISH ASSOCIATION.

SECTION G.—ENGINEERING.

SCOTTISH-GROWN TIMBERS FOR AEROPLANES AND PIT PROPS.

THE proceedings of Section G, which met in the lecture theatre of the Engineering Department of the University, commenced on Thurdsay morning, the 8th inst., the chair being taken by Professor A. H. Gibson, D.Sc., who is president of the section. After making a few announcements with reference to excursions, the chairman called on Professor T. Hudson Beare to read a paper describing an inquiry into the suitability of Scottish-grown timber for aeroplanes and pit props. This communication dealt with a series of experiments carried out for the Ministry of Munitions, in which samples of timber were tested as beams on a 20-in. span, the load being so arranged that no shear stress occurred on the 20-in. length forming the central portion of the sample. From the unstressed ends of each sample, specimens were cut and turned for compression tests, and the limit of elasticity for the beams was also carefully determined by means of a deflectometer. After the beams were broken, tests were made of the percentage of moisture present, the widths of the annual rings were measured, and the nature of the growth of the wood examined. In the case of the tests of timber for pit props, which tests were made for the Forestry Commission, the props were tested as received with the bark left on, but the ends were carefully squared and the loads were applied by means of compression blocks with spherical seatings in order to ensure the load being applied axially. The results obtained indicated that a light variety of Scots fir having narrow annual rings and weighing from 28 lb. to 34 lb. per cubic foot, with 15 per cent. of moisture, could be used as a substitute for silver spruce in solid form for aeroplane work. At its best, this timber was, in fact, superior to silver spruce. A heavier variety of Scots fir from England, weighing from 37 lb. to 43 lb. per cubic foot with 15 per cent. of moisture, could also be used in box spars or with light wood in laminated members. For a good Scots fir, the value of E was from 1,785,000 lb. per square inch to 1,907,000 lb. per square inch, and the elastic limit stress varied from 4,048 lb. to 6,700 lb. per square inch. The figures given for the maximum stress were 7,753 lb. to 12,044 lb. per square inch. In the case of the timber for pit props, the author gave the following figures as the average crushing strengths obtained on a large number of specimens, all about 40 in. in length and ranging from 2½ in. to 9½ in. in diameter:—Scots fir, 3,958 lb. per square inch; spruce, 4,237 lb. per square inch; larch, 4,192 lb. per square inch; and Japanese larch, 3,089 lb. per square inch. These tests indicated that the strength of British grown timber was ample for the purpose and although the author had no definite information as to its durability under mining conditions, he saw no reason why it should be in any way inferior in this respect.

MECHANICAL PROPERTIES OF SCOTS PINE.

At the conclusion of Professor Hudson Beare's paper, the chairman said that before opening the discussion on it he would ask Professor A. R. Horne, O.B.E., to read his paper on the "Mechanical Properties of Scots Pine," and the two papers would afterwards be discussed together. We reprinted Professor Horne's paper on page 387 of our last issue, so that we may now proceed to deal with the ensuing discussion.

The chairman, in opening the discussion, said he thought such papers as they had heard would give considerable impetus to the forestry developments now going on in Scotland, and that the community would eventually become self-supporting in the matter of timber supplies of the kind referred to. He wished himself to ask the authors one or two questions of which the first was addressed to Professor Horne, the chairman asking him to explain the meaning of a moisture content of over 130 per cent. given in the table accompanying the paper. He also said that, with reference to Fig. 1 of Professor Horne's paper, it seemed difficult to confine the results to any particular curve. The speaker also pointed out that both authors were in agreement on the point that the lightest Scots pine was the best.

The first speaker in the general discussion was Mr. J. S. Wilson, who remarked that the engineer's greatest difficulty with regard to the use of timber was to know what stress could be safely employed. The durability of timber structures, the speaker continued, was remarkable, but it was difficult to apply the results of tests of strength to the design of actual structures. He inquired how Professor Hudson Beare's compression tests on small specimens agreed with the results obtained on full-size props, and also asked how the necessary allowance for dryness was to be made in practice. In conclusion the speaker explained that he had spoken mainly for the purpose of persuading persons who made experiments on the strength of timber to keep in mind the needs of the practical engineer.

The next speaker, Dr. J. S. Owens, inquired as to the strength of timber when fully saturated, which was the condition of marine structures, piles, pit props, &c. The whole question of the effect of moisture on the strength of materials was one of considerable importance, and the speaker mentioned that at the Portsmouth meeting of the British Association he had pointed out that the strength of Portland stone when saturated with water was about 30 per cent. less than its strength when dry. This, however, was all part of a larger question which included the effect of moisture on all porous materials, a subject which the author said required careful investigation.

The discussion was continued by Mr. C. E. Stromeyer, who pointed out that he was an amateur in mining matters, but said that he understood that it was highly desirable that the timber used for pit props should give some warning of failure before the actual collapse occurred. Oak, he said, gave no warning, but larch gave ample warning before giving way. Another point referred to by the speaker was that, in some mines, the ends of the props were tapered, so that the tests with flat ends would not apply to these. He also referred to the curves given in Fig. 1 of Professor Horne's paper, remarking on the difficulty of expressing such results mathematically.

The next speaker, Mr. R. V. Southwell, inquired if Professor Hudson Beare did not really mean limit of proportionality when referring to limit of elasticity. The speaker inquired if there existed any experimental evidence that the material became inelastic at the point referred to.

Professor Henry Briggs, who followed, said he was interested in pit props, but he thought the question of straightness of growth of timber rather tended to vitiate the results obtained in laboratory experiments. British timber was faulty in this respect, and it had been found necessary to employ five British props where three of foreign growth would have been sufficient; this was because all the British props were crooked. Professor Hudson Beare's specimens, he noticed, were all straight, and he did not understand why they could not be grown as straight in this country as in Scandinavia. Durability, the speaker continued, was not a matter of first importance in connection with props. He was surprised to hear a previous speaker's reference to oak as a treacherous material since it was not used in mines, and for general structural work it was eminently satisfactory.

The last speaker in the discussion was Professor R. Robinson, F.R.S., who said he disagreed with Professor Hudson Beare's conclusion that Scots fir was a suitable material for aeroplane construction. The speaker said he had tested numerous samples, of which quite 90 per cent. were defective with regard to straightness of grain. Scots timber, he said, had a wavy grain with numerous knots, which, if they occurred in a stressed part, were a source of failure. The timber was also generally brittle in character and was also difficult to glue, as was any timber containing resin. Silver spruce, the speaker continued, was the most satisfactory timber with regard to glueing. He could hold out no hopes that the demand for a satisfactory timber for aeroplane construction could be supplied by the Scottish forests. With regard to the second paper, the speaker thought it difficult to draw conclusions from the results of timber tests which, when plotted, looked like a constellation. He would be glad to know if this were due to defects in the apparatus or to the method of interpreting the results. He did not approve of the use of the "modulus of rupture" since it assumed conditions which did not hold at the time of fracture. Failure, he said, was really occurring as soon as the elastic limit was passed, and he thought that if the load on a beam which first produced a deviation from the straight-line diagram were left on long enough, the beam would ultimately fail; the time effect was very definite after the elastic limit. To the previous speaker who had raised the question of the effect of saturation on the strength of timber, Professor Robinson remarked that this hardly came in, as after a certain amount of moisture had been absorbed the strength became uniform up to saturation. In designing timber structures, he suggested that for structures to be used in the open air the stress allowed should be based on figures for green timber, but for aeroplanes and other work, which was protected by varnish, &c., from the effects of the atmosphere, the design should be based on a moisture content of 14 per cent.

At the conclusion of Professor Robinson's remarks, the chairman called on Professor Hudson Beare to reply to the points raised in the discussion. Professor Beare then replied briefly to one or two questions. With regard to the agreement between the results of tests on large and small specimens, he mentioned that, in the case of Japanese larch, the crushing strength was 2,170 lb. per square inch with the full-size specimens and 3,145 lb. per square inch with the small specimens. As to the durability of timber structures he referred members to a part of the old roof of Carstairs station now placed in the entrance hall of the Engineering Department. The speaker mentioned that this roof had been in service for about ninety years, but was still in a perfect state of preservation. In answer to the last speaker's remarks as to Scots fir being inferior to silver spruce, Professor Beare said he had not himself selected the timber used in his tests, but he had found very few specimens with knots, and it was generally straight grained. Professor Horne, who was then invited to reply, referred first to the chairman's query as to the meaning of 130 per cent. of moisture. This, Professor Horne explained, meant that the weight of the wood as cut was 2·3 times as great as when it was perfectly dry. He agreed with several speakers that it was probably a mistake to endeavour to express the strength of timber by means of an equation, and with respect to the knotty character of Scots timber he thought this was largely due to the fact that the lower branches of the trees were left on in order to provide cover for game.

STRESSES IN SHIPS' PLATING.

After thanking the authors of the two previous papers, the chairman called on Dr. B. C. Laws to read his paper on "The Stresses in Ship's Plating Due to Fluid Pressure," which will be found reprinted in full on page 368 of our last week's issue. Professor F. C. Lea, the first speaker in the discussion which followed the reading of this paper, expressed appreciation of Dr. Laws' work, which he pointed out differed somewhat from Grashof's in that the maximum stress was found to occur at the centre of the longer sides instead of at the centre of the plate. Professor Lea inquired what was the effect of increasing the ratio l/b and what was the effect of varying the thickness of the plate, the latter being an important point in connection with the design of reinforced-concrete slabs. Another matter on which Professor Lea desired information was the effect of the nature of the support on the stresses produced.

The only other speaker in the discussion on this paper was Mr. C. E. Stromeyer, who said he had dealt with the subject by analysing experiments made and by studying the Board of Trade reports on boiler explosions. The conclusion he had arrived at was that the working pressure, or bursting pressure, on a flat plate could be expressed in terms of the thickness of the plate and the diameter of the inscribed circle. The expression for the working pressure in pounds per square inch, he said, was $W.P. = 360 \frac{t^2}{d^2}$, where t was the thickness of the

plate in sixteenths of an inch and D was the diameter of the inscribed circle. For the bursting pressure the constant would be from 1,200 to 1,600.

In calling on the author to reply, the chairman inquired if the formulæ quoted by Dr. Law had been deduced from experiments or obtained by theoretical analysis and also asked if tests had been made to determine the effect of alteration in the length of the stiffeners. Dr. Law, in replying, said that he had at that time in contemplation some experiments which would deal with the second question raised by Professor Gibson, and added that his expressions had been obtained by the analysis of experimental data by the method of finite differences. In reply to Professor Lea, the speaker explained that he had not been able, for practical reasons, to proceed to the limiting ratios for *l/b*. The plates used had ranged from 3 ft. 6 in. to 14 in. in length of side and they had "rung the changes" on five different areas. In answer to Mr. Stromeyer's remarks, the speaker said he had made no experiments on boiler plates, but it was possible that some would be carried out in the future.

The research referred to in the paper relates to fixed steel plates only. The derived expressions therefore could only find application to concrete slabs if they were fixed and the concrete considered to offer resistance to tension, and even then only within the limit of stress fixed by the value of the latter, and provided also the concrete were more or less homogeneous in character, *i.e.*, if the larger aggregate were not too large. With reinforced concrete the conditions would be entirely changed, and would be such that the expressions given are not applicable. Here the rods forming the reinforcement perform their functions not as parts of a homogeneous whole but more or less as separate units. They were subject to lateral loading as well as direct tension (or compression) due to the change from straight to curvilinear form, and the actual stress in the material would be of the nature of that indicated in his (the author's) paper on the "Thin plate beam" contained in Vol. 32 of *The Philosophical Magazine*. He (the author) appreciated in the fullest sense the kind references made by Professor Lea to his work. The research is nearing completion and, it was hoped, would be available for publication at an early date.

The Fracture of Wire in Steel Ropes.

The chairman then called on Dr. E. M. Horsburgh to read the next paper on the programme, which dealt with the mathematical principles involved in examining the strength of steel ropes, and the fracture of wires in ropes. The experimental work was carried out at the research laboratories of Messrs. Brunton, Musselburgh. The paper, with which we hope to be able to deal more fully in a later issue, was divided into eight sections, but lack of time prevented the author from dealing fully with more than the first two of these relating, respectively, to the forces in rope wires and the rope modulus. The author drew a comparison between the stress-strain curves for a rope and a structural steel member, and obtained a mathematical expression for the former. Of the remaining sections, the author had only time to mention the headings and outline the work. These sections, we may add, related to the efficiency of a steel rope, tension and torsion in rope wires, spring effects in winding, effects of wear, and effects of ageing. In conclusion, the author mentioned that he had arranged a number of specimens of winding and haulage ropes in another room to show the damage they had sustained in use.

In the brief and hurried discussion which followed, the first speaker, Mr. J. S. Wilson, after congratulating the author, said he would like to have heard the paper in full and hoped that it would be published so that the members would be able to study it later.

Professor Lea, who followed, pointed out that one of the stress-strain curves used by the author was for mild steel and was not comparable with that for the steel used in wire ropes. The curve for the wire rope was very similar to that obtained with cold-drawn steel wire in which no discontinuity occurred such as was found with mild steel.

Professor C. H. Bulleid, the only other speaker, mentioned the case of a failure of a wire rope after 2½ years' service. He had taken a sample of the rope close to the fracture and another from the disused portion on the drum and subjected them to tests in which he found low tensile strength and elongation in the part subject to use. He had tried the effect of annealing the wires, and had found that the tensile stress went down and the elongation went up in both cases. The unstressed portion was thus still stronger than the other even after both had been annealed. The speaker had therefore assumed the failure to be due to fatigue, and he asked the author if he considered the assumption was correct.

In reply, the author stated that Professor Lea was correct in his remarks relating to the stress-strain curves. The whole point, however, turned on the question of microstructure, as he would have explained had he had time. The question of fatigue was one of great importance, as also was that of ageing. He had been carrying out some experiments on the latter, but unfortunately the specimens had been thrown away by accident. He would like to mention that one of the severely-treated ropes on view in another room when examined under the microscope showed but little difference between the outer layers which had been greatly cold-worked and the inner layers which were comparatively soft.

Width of Test Pieces.

The chairman having expressed his regret that time had not permitted the meeting to hear Dr. Horsburgh paper in full, called on Professor Hudson Beare to read his paper dealing with the influence of the width of the specimen on the results of tensile tests of mild steel and rolled copper. Professor Hudson Beare then briefly summarised his paper, which will be found on page 389 of our last issue, and at its conclusion Mr. R. V. Southwell remarked that the corrugation of the edges of the bars referred to by the author was exactly similar to that found in the tests of fabric. He thought this might be due to the existence of cross stresses and that this might account for the wavy nature of some of the diagrams included in the paper. He suggested that Professor Coker's optical method might be utilised to investigate the point. Professor Mason, who also spoke, said he would have expected to find the effect of width and thickness on the reduction of area and extension to be greater than that found by the author.

No further time being available for discussion, the chairman called on the author to reply, which he did very briefly. With regard to the existence of cross stresses suggested by Mr. Southwell, the speaker said he did not think they would occur, although the specimens certainly approximated to fabric.

The chairman, after thanking the author, stated that the work of the morning had been completed, as Professor Henry Briggs' paper on "Rescue Apparatus for Use in Mines," which appeared on the programme for that morning, would be taken on Wednesday morning, the 14th inst., instead. The meeting then adjourned, and in the afternoon the members visited either the electrical engineering works of Messrs. Bruce, Peebles and Co., Limited, Edinburgh, or the shipbuilding yard of Messrs. Ramage and Ferguson, at Leith, and the Leith Docks.

Water Power.

Professor A. H. Gibson, the president of the section, delivered his address on the subject of "Water Power," which we reprint in full on page 420 of this issue, at a well-attended meeting on Friday, the 9th inst. The address was, of course, not open for discussion, but Professor T. Hudson Beare, in proposing a vote of thanks to Professor Gibson, stated that the importance of water power had been brought home to the public with special force during the recent coal strike. "White fuel," he continued, was one solution of the problem of the reduction of power costs, which were mounting up steadily even before the war. The president, the speaker mentioned, had referred to the question of labour-saving and had given some striking figures comparing the labour required for power production from water and from coal; this, he said, was an aspect of the subject that could not be neglected. Reference had also been made in the address to the lack of certain essential data such, for instance, as the actual flow of streams and the loss of water by evaporation, and the speaker mentioned that he had been carrying on experiments on the latter subject for upwards of fifteen years. More reliable data were, however, required. The speaker was also in complete agreement with the suggestion made towards the close of the address that it was necessary to establish a research laboratory to deal with water power problems. There could be no question, the speaker stated, that valuable work had been done in steam-power laboratories, and he thought that equally useful work could be carried out in connection with water power if support were received from the public and the State. The laboratory they had at the University was on too small a scale. At the same time he pointed out that it would be too expensive for all educational establishments to carry out large-scale hydraulic experiments, so that the better plan would be to establish a central laboratory for large-scale work and utilise the existing smaller ones for preliminary training. He then proposed a vote of thanks to the president for his interesting and valuable address, and this was carried with acclamation.

Professor Gibson then called on Professor F. G. Baily to read his communication on the linking-up of the smaller water powers in Scotland, which communication will be found on page 410 of this issue. Before doing so, Professor Baily explained that an examination of the map of Scotland would show large areas of land at a considerable height from which the rivers generally ran gradually down for a distance of from 100 miles to 150 miles without any sudden descent. It was therefore difficult to employ them in large power schemes. Only about 5 per cent. of the total water power in Scotland, which amounted to some 7,000,000 h.p., could be utilised in that way, but a considerable proportion of the remaining 95 per cent. could be employed on the system he was about to put before the meeting. This scheme, which is dealt with in the communication above referred to, was then explained in detail by the author, and at the conclusion of his remarks the chairman suggested that Professor F. C. Lea should read his paper on "The Utilisation of Tidal Power, with Special Reference to the Severn Estuary," and that the two papers should afterwards be discussed together.

But little time remained, and Professor Lea therefore summarised his paper, which we reprint on page 424 of this issue, showing the diagrams as lantern slides and explaining each. This, however, occupied the meeting until the time for adjournment, so that the discussion of both papers had to be omitted. The chairman, who expressed regret that this should be necessary, remarked that Professor Lea had adopted a somewhat pessimistic attitude towards the scheme. He wished to mention, however, that the Board of Trade Water Power Resources Committee had appointed a small sub-committee, including Sir Phillip Dawson and himself, to form a rough estimate of the cost of the scheme; not, he explained, the grandiose scheme of the Ministry of Transport, but a less ambitious one involving a barrage at Beachley. Their investigations had shown that power could be developed continuously at a cost of 0·7*d.* per unit, although the figure had been arrived at some two years ago when constructional costs were at a maximum. It was therefore not financially impossible at the moment, and if it should prove possible to modify metallurgical processes, &c., so that they could work with an intermittent supply, it was probable that such a scheme could produce power at a lower cost than any other.

The chairman then proposed a vote of thanks to Professor Lea for his paper, and the meeting terminated. In the afternoon the members visited the wire mills of Messrs. Brunton, at Musselburgh.

Seaplanes.

The first business dealt with when the section resumed on Monday, the 12th inst, was a paper by Squadron-Leader A. J. Riley, on Seaplanes. The author, in introducing his subject, said that both seaplanes and amphibians might be described as being in their early infancy. Great strides, he said, had been made during the last ten years in the design of aeroplanes, but the progress in seaplanes was less marked. Seaplanes, Mr. Riley pointed out, might

be divided into two main classes, viz., the float type and the boat type—the latter being frequently referred to as flying boats. With regard to machines of the float type, several examples of which the author illustrated by means of lantern slides, he explained that these machines could be easily handled on shore and could be beached on a smooth shore without damage; their arrangement was favourable to stability, both in the air and on the water, and they had the additional advantage of being easily convertible to aeroplanes or *vice versâ*. There were, he continued, three possible arrangements of floats, viz., two main floats with a single tail float, two longer main floats without a tail float (*e.g.*, the Wight seaplane) and a single large central float in conjunction with two small floats attached to the wing tips; the latter arrangement, the author remarked, was but little used in practice, although it had the important advantage of presenting the minimum obstruction to the field of view of the pilot.

Coming to the boat-type seaplane, of which numerous examples were also illustrated on the screen, the author pointed out that, in these machines, the fuselage and float were combined in a single structure which formed the hull. For lateral stability on the water, reliance, he said, had to be placed on wing-tip floats, while longitudinal stability was provided by the length of the hull. The advantages of the boat type over the float type were that the machines of the former class could be built lighter, had a lower air resistance, and were more satisfactory in disturbed water. As a result of these advantages, boat seaplanes had gradually increased in size, while the float type had remained comparatively small. The hulls of the boat-planes were, however, rather delicate, and it was important when handling boat seaplanes on shore, that the hull should be placed in exactly the correct position on the trolley in order to avoid damage.

Dealing with the effect of propulsion on design, the author remarked that it was necessary to provide at least 3 ft. clearance between the tips of the propeller blades and the water line, which meant that a high thrust axis must be accepted. Placing the thrust axis above the centre of gravity of the machine, of course, introduced a downward pitching moment, but the effect of this could be diminished, or eliminated, by suitably setting the tail plane and placing it in the slip stream of the propeller.

The remainder of the paper dealt with the design of hulls for boat seaplanes, but as the time allotted had been practically exhausted, the author had to curtail this most important part considerably. He was able, however, to show cross sections of nine different forms of hull and illustrate the water resistance curves obtained for some of these from experiments carried out in the William Froude Experimental Tank at the National Physical Laboratory. The annexed table, which the author was unable to show at the meeting, gives the principal dimensions and other design data for these hulls.

The Chairman, Professor A. H. Gibson, then expressed regret that the author had been unable to give his paper in full and added that it would be impossible to discuss it, since, in accordance with the programme, it was then necessary for the Section to adjourn to the Old College for the joint discussion with Section C (Geology) of the Mid-Scotland Canal.

The Mid-Scotland Canal.

The joint discussion on the above subject was held under the chairmanship of Dr. J. S. Flett, F.R.S., President of Section C, who first called on Mr. Murray Macgregor to give an account of the geological features of the scheme. Mr. Macgregor then explained the two proposed routes, one of which is known as the direct route and the other as the Loch Lomond route, both being intended to provide communication for ships between the Firth of Forth and the Firth of Clyde. The direct route, he said, had a total length of 51¼ miles, while the length of the Loch Lomond route was 71¼ miles. Both canals left the Forth near Grangemouth and the former proceeded in a more or less straight line at sea level joining the Clyde between Clydebank and Yoker, traversing an important industrial and mining area *en route*, while the latter, which was a lock canal, traversed an agricultural district, passing near Stirling, along the valley of the Forth to Drymen, through Loch Lomond to Tarbet and thence down Loch Long to the Clyde.

The two routes referred to, Mr. Macgregor said, were the only ones possible, and to compare them, it was necessary to consider the different elements of which each was composed. The direct route, he continued, contained 47½ miles of artificial waterway, while that for the Loch Lomond route was 40¾ miles. The lengths of natural waterway on the two routes were 4 miles and 30½ miles, respectively, while the rock cuts were 18 miles and 15 miles, and the soil cuts 11 miles and 25¾ miles respectively. The total length of ground, 50 ft. above sea level, was 22½ miles on the direct route and 12 miles on the Loch Lomond route, while the corresponding figures for ground, 100 ft. above sea level, were 20¼ miles and 9 miles respectively. In no part of either route did the ground rise above 250 ft., whereas in any other route selected, heights of at least 500 ft. would be encountered.

Mr. Macgregor said that preliminary surveys of both routes had been made and he proceeded to deal with the geological features of the direct route with the aid of vertical and horizontal sections exhibited as wall diagrams, but pressure on our space will not permit us to follow him in this.

Mr. C. H. Dinham, the next speaker, dealt in a similar manner with the geology of the Loch Lomond route, explaining that, west of Stirling, the economic features of this route were unimportant, though, as far as Stirling, it passed through a coal-field. In neither route, he added in conclusion, were the geological features of sufficient importance to give it any outstanding advantage over the other.

Mr. D. A. Stevenson, who followed, read a statement which we shall reprint in an early issue, advocating the Loch Lomond route, and he was followed by Mr. Robert Bird, who spoke in favour of the direct route.

Mr. Bird pressed the commercial importance of a canal passing through industrial country with large engineering and mining districts, and mentioned that 25 industrial centres were situated within a short distance of the direct route. He suggested that the Government should employ a number of impartial engineers to decide as to the feasibility of the scheme, and to estimate the probable cost so as to settle existing differences of opinion as to the merits of the rival routes. As far as the speaker, and his company, were concerned, the question had been settled quite ten years ago in favour of the direct route, and he thought he was entitled to say that that route held the field at the present time. The Admiralty, he added, had admitted the advantages of the scheme from a strategic point of view, but the speaker did not want a canal which was of use in war time only; it must also be of commercial utility in peace time. They had not, however, yet succeeded in convincing the Board of Trade who had estimated the probable traffic through the canal as only 3½ million tons per annum. The speaker's estimate of the traffic was 23 million tons per annum, and he had also estimated that the saving due to the canal on a round voyage of a tramp steamer from the Clyde to the Baltic would be about £700. In conclusion, he pointed out that the construction of the canal would afford an excellent means of relieving unemployment.

Mr. Salveson, who continued the discussion, questioned some of the figures issued by the promoters of the canal schemes, giving the possible savings to shipowners in time and money. At least 24 hours, the speaker said, would be occupied in the canal passage, and even if it were possible to save six days on the round voyage from Glasgow to the Baltic, the cost of the trip would only be reduced by 1,188*l*. Allowing 700*l*. for canal dues the total saving would be 488*l*. instead of 700*l*. Actually, the speaker considered, the time saving would not exceed two days, and, that being the case, the use of the canal would result in a dead loss of some 300*l*. for the trip. From a commercial point of view, the speaker regarded the whole scheme as quite impracticable, and, although it might be useful in war time, he did not consider the expenditure on it would be justified in view of the present efforts to reduce expenditure on armaments.

The following speaker, Mr. H. M. Cadell, said he foresaw many difficulties in connection with the construction of the canal, and did not think it could possibly pay its way. The cost of excavation alone, he said, would amount to about 35,000,000*l*. It had been stated that the direct route canal would benefit the industrial district through which it passed, but he wished to point out that mine owners would be sorry to have a deep canal cutting anywhere near their pits owing to the risk of flooding their workings. The speaker regarded the Loch Lomond route as generally preferable from the engineering point of view, but pointed out that serious geological difficulties were likely to be encountered near Tarbet, owing to fissures and landslips.

The next speaker, Mr. P. D. Ridge-Beedle, said the decision as to which route was preferable would have to be arrived at on the question of cost. It was stated by advocates of the Loch Lomond route that their scheme had advantages from the strategic point of view, although they were extremely reticent as to what these advantages were. The speaker's view was that the Loch Lomond route was inferior to the direct route from this standpoint, since, if the locks were destroyed by enemy action, the fleet might be imprisoned in Loch Lomond or even left high and dry by the draining of the Loch.

TABLE GIVING PARTICULARS OF FLYING-BOAT HULLS.

Name.	Length Overall.	Length from Stern to Forward Step.	Length Between Steps.	Length from Aft Step to Stern.	Distance of C.G. Above Step.	Horizontal Distance of C.G. from Step.	Beam.		Displacement.	* Angle Between Wing Chord and						Tail.
						A, aft. F, fwd.	Hull.	Chine.		Forward Step.		After Step.		Line Connecting Steps.		
										Keel.	Chine.	Keel.	Chine.	Keel.	Chine.	
	ft. in.	ft. in.	ft. in.	ft. in.	ft.	ft.	ft. in.	ft. in.	lb.	deg.	deg.	deg.	deg.	deg.	deg.	deg.
1. F.B.A.	26 2	9 1	—	17 1	—	0·82 A	3 9	3 6	2,000	+ ¼	¼—	—	—	—	—	−10
2. Norman Thompson N.T.2B	24 0	12 4	—	11 8	—	2·27 F	4 3	3 11½	3,170	−2½	¼—	—	—	—	—	−11½
3. A.D. Boat	30 0	13 6	8 0	8 6	5·8	1·16 F	3 8	4 20	3,567	−3½	−4½	−3½	−3½	− 9½	− 7½	−23½
4. F.8	45 0	21 6	7 0	16 6	6·6	3·33 F	5 0	10 0	12,250	−3½	−3½	−6	−6	− 9½	− 9½	−21½
5. Phœnix Cork No. 1	45 0	18 0	18 0	9 0	7·0	0·25 F	5 8	7 6	11,600	−2½	−2½	−8½	−4	−11½	− 8½	−18
6. "Felixstowe Fury"	60 0	27 2	9 4	23 6	10·6	4·6 F	6 0	11 6	25,250	−1	0	−7	−0½	−10	− 4	−19½
7. Vickers' Valentia	53 0	21 6	14 0	17 6	9·5	0·55 F	5 0	9 6	18,500	−5	−5	−9	−6½	−11½	−11½	−18
8. Fairey Atalanta, Linton-Hope design	64 0	21 10	30 2	12 0	11·2	1·9 A	8 6	9 6	32,000	−2	−2½	−7½	−4½	−12	− 8½	−17½
9. Fairey Atalanta, Camper and Nicholson design	64 0	24 8	25 0	14 4	10·0	1·66 F	—	10 9	32,000	−5	−4	−12	−9½	−12½	− 9	−14½

* A positive angle is measured upwards from the horizontal.

With the direct route, which was a sea-level route, such an eventuality would not be possible. The cost must, however, be the deciding factor, and it was necessary to divide the cost with two parts—one of which might be called the investment cost and the other the dead cost. To explain his meaning, he instanced works costing, 35 millions, and bringing in a revenue of 1¼ millions, so that a dividend of about 6 per cent. could be paid on 20 millions. The latter expenditure, he said, could be regarded as an investment, but the remaining 15 millions had to be put down as a loss. From this point of view also, he considered that the direct route had an overwhelming advantage. The speaker also called attention to the industrial advantage of the direct route of the district through which it passed, and added that the Manchester Ship Canal was an example of what might be expected. The latter canal, he also pointed out, had a dead end at Manchester, so that a canal which provided a direct route to the sea in both directions might be expected to have an even greater effect on industrial development. He had no doubt that it would pay after a few years.

Lieut.-Col. W. L. Forbes, who followed, said he wished to correct some points made by previous speakers. The advocates of the Loch Lomond route, he said, had never made any secret of the strategic advantages of that route, and to those speakers who had stated that the canal could not be made to pay, he wished to say that this opinion was very prevalent in Great Britain with regard to canals in general; they had, however, found to be of commercial advantage to practically every other country in the world by providing cheap transport facilities. The direct route, the speaker concluded, had two drawbacks; one was the very deep trench required, and the other was that battleships and other very large vessels built at Glasgow would seriously impede the canal traffic.

Mr. J. MacDougall remarked that it was necessary for a decision to be come to as to which of the routes was the more practicable, and urged the necessity for the Government to deal with the matter. The construction of a canal, he said, was not a Scottish question, but a national one, and the cost should not be considered too seriously.

The last speaker, Mr. Arnold Lupton, said the cost of the Loch Lomond route had been estimated in pre-war days at 24 millions for a canal 30 ft. deep. The canal now proposed was 45 ft. deep, which would double the above figure for the cost. At present day prices, that figure would be again doubled and the cost might therefore be put at 100 millions in round figures. The cost of the direct route had been stated to be 50 per cent. higher than that of the Loch Lomond route, so that the cost of the former might be put at 150 millions. He asked if this figure were correct. With regard to the Manchester Ship Canal, referred to by a previous speaker, Mr. Lupton pointed out that this had been constructed for the development of the trade of Manchester, whereas the canal they were then discussing was for the development of inter-ocean traffic. He did not consider that any analogy could be drawn between the two with respect to the development of industries along the routes. The speaker also emphasised the strategic value of the canal.

At the conclusion of Mr. Lupton's remarks, the Chairman said that as the time limit had been reached, it was necessary for him to bring the discussion to a close. They had, he said, heard competent authorities on all sides, and the discussion should certainly serve to open the minds of all present. He had been struck with Mr. MacDougall's suggestion that a Government enquiry should be undertaken to obtain the facts of the case for the use of engineers and business men, and, if that were done, Sections G and C would certainly have accomplished some useful work in bringing the question forward for discussion.

The meeting then adjourned, the Members of Section G visiting the laboratories of the Heriot-Watt College in the afternoon.

EDINBURGH ELECTRIC POWER STATION.

Owing to the absence of the author, Mr. S. B. Donkin, whose paper on the new electricity supply station of the Corporation of Edinburgh formed the first item on the programme of Tuesday's meeting, this interesting paper, which we reprint on page 422 of this issue, had to be taken as read, and there was no discussion on it.

REPORT OF COMMITTEE ON COMPLEX STRESSES.

Professor A. H. Gibson, who again occupied the chair, then explained that it had been decided to take the Report of the Committee on Complex Stress Distributions in Engineering Materials, which it had been originally intended to deal with on the following day. This report, of which we hope to give a full abstract in a future issue, is divided into nine sections, the first, by Professor E. G. Coker and Dr. P. Heymans, dealing with stress concentrations due to notches and like discontinuities. In the absence of Professor Coker, the chairman called on Dr. G. Cook to read his section of the report relating to the distribution of stress in a flanged pipe. This Dr. Cook did in abstract, explaining that the paper gave an account of an analytical and experimental investigation of the effect on the stress in the wall of a tube subjected to internal pressure, of a constraint limiting the deformation at some point of its length. The practical value of the investigation, he said, was that it could be applied to the determination of the most effective spacing of the bands in reinforced steel pipes, and also to determine the stresses likely to exist in such pipes. An investigation of that particular problem, he said, was proceeding at the present time.

At the conclusion of Dr. Cook's remarks, the chairman, in inviting discussion on the paper, said that the thickness required for some of the mains used in connection with hydro-electric power plants was so great that it had been found impossible to rivet them, and very difficult to weld them. It had therefore been decided to loop the pipes, and steel bands, up to about 2 in. square in section, had been shrunk on. Dr. Cook had been endeavouring to determine the best pitch for the bands, and had found that they were of practically no use unless spaced so closely that they almost touched. This result, the chairman remarked, was rather surprising but was extremely valuable.

Mr. C. E. Stromeyer, who spoke first in the discussion, referred to certain German experiments on the longitudinal compression of boiler furnaces. They had been carried out on flanged, corrugated and ribbed furnaces, and, as the results had been published, he thought they would add to the information contained in the paper.

The only other speaker on Dr. Cook's communication was Mr. R. V. Southwell, who remarked that he hoped the author would consider the case of shrunk-on flanges, in addition to the case of flanges which were constructed solid with the pipe.

The next section of the report was one by Professor L. N. G. Filon, on stresses in multiply-connected plates, but, as Professor Filon was not present, the chairman asked Professor B. P. Haigh to read his section, which dealt with the strain-energy function and the elastic limit. Professor Haigh then explained that his paper was a continuation of that read at the Bournemouth meeting of the Association two years ago. It was, however, of a rather more theoretical nature, and he was afraid it would not be of such direct practical importance. He hoped, nevertheless, that it would prove interesting, and proceeded to deal briefly with each of the main headings. These related to the physical theory of non-elastic strain, thermodynamic principles, Professor James Thomson's work on "Regelation," the thermodynamic reversibility of the stages of strain, and the expression for the work done in the reversible stage of strain.

The first speaker in the discussion which followed the reading of this section of the report was Mr. R. V. Southwell, who referred to the difficulty of obtaining a theory of breakdown which would apply to all kinds of complex stresses. The author had, however, given a theory, and it was satisfactory to have something physical as a basis of definite rules which, by themselves, seemed to be far from giving a real idea of what was actually going on. The speaker found it difficult to conceive of a material failing under hydrostatic pressure, however great that pressure might be. If a uniform hydrostatic pressure were applied at all parts of a body, it would diminish the distance between the molecules, and that might go on indefinitely. He could not imagine any elastic failure or yielding under such conditions. An interesting feature of the paper, Mr. Southwell continued, was the suggestion it contained that the formation of amorphous material was preliminary to the gliding of the crystals, and not a consequence of that movement. He had always imagined that the contrary was the case, but he thought the matter could be settled experimentally, and asked what was the experimental evidence on which the author's suggestion had been founded. If it could be established, it would be extremely interesting, and he would be glad to believe that it was so. The speaker also enquired what evidence there was of change of density in changing from the crystalline to the amorphous state. It would, he thought, be practically impossible to observe the density of the amorphous material, and he would like to know if there were any evidence that the amorphous material was less dense than the crystalline.

The next speaker, Professor F. C. Lea, said he regarded the paper as a serious attempt to solve a problem of considerable practical importance to engineers, viz., the manner in which the failure of materials occurred. He had not yet had time to read the paper in detail, but was inclined to doubt the validity of some of the assumptions made as to crystalline and amorphous materials. Curious instabilities, he said, occurred when amorphous material was produced. In drawing steel tubes, for instance, the metal would be greatly overstrained and the material would be in the amorphous condition. There was, however, a rather rapid change towards stability after the metal came from the dies. It was a well-known fact that a tube could be straightened immediately after drawing more easily than it could be if left for a day or two, and, if it were desired to convert a tube drawn to a circular section in to one of oval section, it should be put through the oval die as quickly as possible. The drawn material was found to have a low elastic limit of about 8 tons or 9 tons per square inch, to exhibit "creep points" in tensile tests and to have an ultimate tensile strength of about 35 tons per square inch. The elastic limit could be raised and the "creep points" removed by heat treatment. Time and temperature, in fact, always led towards stability, and he found it difficult to form a mental picture of the change taking place on the allotropic theory. He had satisfied himself that the change in density which occurred when a metal was compressed could be measured, and had found that an allotropic material had a lower density after compression than before; a result which was rather surprising but was nevertheless a fact. Another interesting fact was that the change in density disappeared if the material were allowed to rest for a month or so, and if heated to about 350 deg. C. it could be removed in about 20 minutes.

Mr. Southwell here explained that, in a block of material such as that used by Professor Lea for his determinations of density, there would be very little amorphous material; probably only about 1 per cent. or less. Professor Lea had therefore only measured the density of a mixture of crystalline and amorphous material, whereas the speaker wished to know the density of the amorphous material alone.

Mr. C. E. Stromeyer, the only other speaker in the discussion, said the explanation given confirmed some experiments of his on the ageing of steel. He had bent a number of nicked plates and measured the curvature to which they could be bent before cracking. He had allowed some of the specimens to rest and immersed others in boiling water, afterwards measuring the curvature again, the curvature being distinctly larger in the specimens so treated. The subject of high hydrostatic pressures, the speaker continued, had been investigated by the United States Geological Survey, using pressures up to 130 tons per square inch. One result obtained indicated that steel and rubber washers, subjected to very high pressures, changed their characters entirely, the rubber becoming hard and the steel soft. When taken out of the pressure apparatus, the edges of the rubber washers had been found to have left an impression on the steel washers. He thought that much of the existing confusion

on the subject would disappear if it were borne in mind that all metals were not of the same nature. Slip bands appeared in some metals under strain, but not in all, and the methods of failure of soft metals differed from those of hard metals. He did not think it possible to deal with the matter as if all metals failed by slipping or all by tearing.

Professor Haigh, who then replied to the discussion, said so many points had been raised that it would not be possible for him to reply to them all. He would first deal with the point raised by Mr. Southwell as to the effect of hydrostatic pressure. If it were true that fluid pressure had no effect his theory would have to be modified, but he did not think that this was the case. If a block of steel were subjected to a very high pressure, there would be a change of state as long as the pressure was applied, but the change would be reversed when the pressure was removed. This might be illustrated by an experiment with a block of ice in which a foreign body was frozen up. If kept at freezing-point and subjected to pressure, the ice would liquefy, but it would solidify again when the pressure was removed, and the only evidence of the change of state would be the movement of the foreign body. The effect of density, the speaker continued, was an interesting point. As a rule metal expanded when strained in shear, but in wire drawing it contracted in volume during the useful range, but afterwards expanded, numerous minute cracks being formed in the metal.

The remaining sections of the report were by Mr. A. A. Griffith, on "Stress Concentrations in Theory and Practice"; by Dr. W. Mason and Mr. W. J. Delaney, on "Alternating Combined-Stress Experiments"; by Mr. R. V. Southwell, on the "Design of High-Speed Discs"; by Mr. Southwell and Miss Gough, on "The Stability of a Rotating Shaft"; and by Dr. G. B. Jeffery, on the "Stresses in Cylinders and Pipes with Eccentric Bore."

The only authors present were Dr. Mason and Mr. Southwell, and the chairman then called upon the former to describe his part of the report. This Dr. Mason did, and at the conclusion of his remarks the chairman explained that owing to the fact that certain pre-arranged wireless signals were to be received in the hall in connection with Mr. Scott-Taggart's paper, it would be necessary to take that paper shortly, so that no further time could be allowed for the discussion of the report. He then asked Mr. Southwell to deal briefly with his part of the report, and expressed regret that it would not be possible to discuss it. In view of the fact that no discussion of the remaining sections took place, it will be unnecessary for us to deal here with the authors' explanations, since, as previously mentioned, the report itself will be published at a later date.

Professor C. E. Inglis' paper on "Two-Dimensional Stresses in Rectangular Plates," which, although on the next day's programme, was to have been read after the report had been dealt with, had also to be taken as read, in view of the lapse of time.

Large Electric Units.

The next paper dealt with was one by Dr. S. P. Smith on "Large Electric Units," and, at the author's own suggestion, the paper itself was taken as read. This paper we reprint in full on page 399 of the present issue. Instead of reading the paper, Dr. Smith showed a large number of lantern slides, illustrating the electrical and mechanical design of the rotors and stators of large turbo-generators and afterwards dealt similarly with the construction of large generators for hydro-electric power plants.

Negative-Resistance Devices.

When Dr. Smith had practically finished his remarks, the Chairman pointed out that it was then necessary to take the two papers by Mr. J. Scott-Taggart, dealing with negative-resistance devices for use in wireless telegraphy. These papers we shall print in full in a later issue, but, in the meantime, we may explain that they describe arrangements of thermionic valves which give negative-resistance effects, *i.e.*, the current flow is increased by a reduction in electromotive force and *vice versâ*. These devices have important applications in wireless transmitting and receiving apparatus, since they materially facilitate the production of electrical oscillations. Mr. Scott-Taggart did not actually read his papers, but demonstrated the use of the "Negatron" valve in the reception of wireless signals from Aberdeen and from the Eiffel Tower. He employed an ordinary valve circuit for reception with a five-stage, low-frequency amplifier and a loud-speaking telephone, which enabled the signals to be distinctly heard in the room. The "Negatron" valve was used to produce the local oscillations necessary for the reception of continuous wave signals by the heterodyne, or "beat," method. The messages were duly received from the above-mentioned stations, that from the Eiffel Tower being as follows:—"French scientists send through the wireless station at Eiffel Tower, Paris, their cordial greetings to colleagues of the British Association at present assembled at Edinburgh." That from Aberdeen was of a similar nature, and both were received with applause.

Long-Distance Transmission of Electrical Energy.

At the conclusion of Mr. Scott-Taggart's demonstration, Professor F. G. Baily, who now took the chair, as Professor Gibson had had to leave the meeting, called on Dr. T. F. Wall to read his paper on "The Long-Distance Transmission of Electrical Energy Generated by Means of Tidal Power." The paper, which we shall reprint later, describes a method of generating and transmitting alternating current at such a frequency that the length of the transmission line, at the lowest turbine speed, will be approximately equal to one quarter of the wave length of the travelling waves of potential difference and current which will be established in the line. As the speed of the turbine increases, the frequency of the generated alternating current will increase correspondingly, and, if the excitation is constant the generated e.m.f. will also increase correspondingly. As the frequency increases, the wave length decreases so that, if at the lowest speed the length of the line is one-quarter wave length, then at double this speed the length of the line will be one-half wave length. Assuming constant current at the receiving end of the line, it is shown that, notwithstanding the rise of the generator voltage as the speed rises, the voltage at the receiver's end of the line will remain constant. The arrangement thus results in an alternating-current supply at the receiver's end of the line of constant voltage and variable frequency. So long as the p.d. is constant and the frequency is high, a variable frequency is not objectionable for heating and lighting apparatus. In order to obtain a supply suitable for driving motors, etc., it is proposed to convert, by means of mercury-arc rectifiers, to direct current, and it is shown that, by such means, a constant alternating-current voltage of variable frequency generated and transmitted in the manner already described, may be transformed to a direct-current supply of constant current and very approximately constant voltage.

Dr. Wall briefly summarised the main points in his paper, and, at the conclusion of his remarks, the chairman called on Professor G. W. O. Howe, D.Sc., to open the discussion. Professor Howe said he regarded the paper as one of extreme importance, since it dealt with a novel method of power transmission. Considerable attention, he said, had been paid to the subject of quarter-wave working, especially in France. He did not, however, intend to discuss the details of the system, but he wished to point out that our present knowledge of the transmission of electric waves along cables was largely due to the work of Dr. A. E. Kennelly, and as that gentleman was present, the speaker would like to ask him to take part in the discussion.

Dr. Kennelly said he was greatly interested in the novel suggestions put forward in the paper, but he thought the suggestion should not be criticised merely on account of its novelty; it was by means of novelties that progress was made. The paper, he said, was the first serious proposition for the transmission of power on a large scale over long distances at telephone frequencies, which were looked upon as high harmonics of ordinary working frequencies. The proposition had been made to work at half the wave-length of the line, but not at quarter wave-length, the latter being regarded rather as a bugbear. The method could, however, be effectively studied in the laboratory, using artificial lines which were relatively inexpensive, and the results of the investigation would be both interesting and useful. He thought the meeting was indebted to the author for presenting his results in the form of curves, and although the computations might be simplified by the use of hyperbolic methods, the means employed were of little importance if the result were correct. In conclusion, he expressed the hope that the matter would be carried further.

Professor F. C. Lea, the next speaker, said he was glad to have heard the paper, since it would be necessary to have the assistance of electrical engineers if the problem of the utilisation of tidal power was to be solved. He wished to ask Dr. Wall if, since in tidal power schemes the machines must run at low speeds, the output would not be low, so that a large number of power units would have to be employed. He inquired if there were any inherent difficulties in this respect.

The only other speaker, Mr. W. Dixon, inquired what was the nature of the current at the receiving end of the line, and, in closing the discussion, the chairman remarked that the paper was a curious inversion of ordinarily accepted principles. Resonance effects, he said, were usually troublesome, and were only employed as a means of eliminating, or emphasising, certain frequencies. Dr. Wall had, however, shown that they might have very useful properties. The idea was certainly very ingenious.

Dr. Wall, who then replied briefly, said that many of the points raised were answered in the paper itself, which he had not been able to read in full. To Professor Lea's suggestion that a large number of units would be required, he replied that, although large, the number would only be about one-half that proposed in the Ministry of Transports' scheme. It was intended to use direct current for power purposes at the receiving end, and at a discussion of the subject at Birmingham it had been proposed to generate and transmit direct current only, but he thought the expense of the scheme would render it impracticable. If direct current were supplied at the distant end, it would be necessary to use it mainly in metallurgical and chemical industries, and, if alternating current were required for local industries, it could be obtained by converting on the site.

After a vote of thanks to Dr. Wall had been proposed by the chairman, the meeting was adjourned.

(To be continued.)

An International Foundry Exhibition at Birmingham.—In connection with the Annual Convention next June of the Institution of British Foundrymen, it is proposed to hold an International Exhibition of Foundry Plant and Materials during the Convention week in Birmingham. The exhibition will be open from June 15 to 24, and be held in the Bingley Hall. It will comprise exhibits from England, America, France and Belgium, and embrace every phase of foundry work. It is the first exhibition of such a nature held in England, and a large influential council has been appointed to make it a success. The organisation of the exhibition is in the hands of the Birmingham Chamber of Commerce. The exhibition will include appliances and materials in connection with the ferrous and non-ferrous foundry trades, and foundrymen will have a unique opportunity to see every class of modern foundry plant.

The late Sir Thomas Salter Pyne.—We regret to have to announce the recent death at Exmouth of Sir Thomas Salter Pyne, who for several years had been chief engineer to the Government of Afghanistan. Sir Thomas was knighted in 1894, and in the same year was made Companion of the Order of the Star of India. He was born in 1860, and received his early education from private tutors. He served an engineering apprenticeship from 1875 to 1878, following which he acted as manager to foundry and engineering works from 1879 to 1883. After serving with a mercantile firm in India from 1883 to 1885, he proceeded to Afghanistan, where he put down works for the manufacture of guns, rifles, ammunition and other industrial products. Sir Thomas acted as ambassador for H. H. the Ameer of Afghanistan to H.E. the Viceroy of India, and at the satisfactory conclusion of the negotiations he was awarded the distinctions above mentioned, and received the thanks of the British Government. His services were also rewarded by an Afghan distinction. During the war, Sir Thomas was employed at the Ministry of Munitions. He became a member of the Institution of Civil Engineers in 1887, and in 1898 a member of the Institution of Mechanical Engineers.

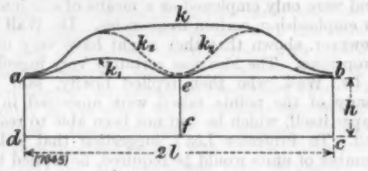
"STRESSES IN SHIPS PLATING DUE TO FLUID PRESSURE."

TO THE EDITOR OF ENGINEERING.

SIR,—I was unfortunate in not being aware that Dr. Laws was reading his important paper on the above subject at the recent meeting of the British Association in Edinburgh, and reproduced on pages 368 and 369 of your last issue. I was therefore unable to comment upon it at the reading. But, as Dr. Laws says truly, "the subject generally is of great importance to engineers," and I am sure you will be able to find space for my few comments.

The first portion of the paper is based on some very valuable papers of Dr. Laws in the *Philosophical Magazine* for 1916, and on his, I believe unpublished, thesis for his doctorate. The latter part is based, I believe, on his paper on "Strength of a Reinforced Thin-Plate Beam, held at its End, and Subject to a Uniformly-Distributed Load—Special Case," published in the *Philosophical Magazine* for August last. It is upon the latter portion that I should like to comment.

The problem is one I have given much attention to, and is that underlying the suggestions in my paper, "A Study of a Ship's Framing," read in March last before the Institution of Naval Architecture, and has since that time been under discussion with Lloyd's Register of Shipping, and with Dr. Laws in his official capacity as a member of the technical staff of Lloyd's Register. In my treatment of the stiffener with free ends attached to a thin plate, details of which were submitted to Lloyd's Register in June last, no account was taken of end tension, and I am glad to see that Dr. Laws has now determined the effect of end tension in his paper in the *Philosophical Magazine*. From my study of the question I have gathered that if the deflection of the uniformly-loaded beams under consideration



a k₂ e k₃ b more nearly represents the stress distribution along *a e b* when *e f* is a rigid boundary. Compare *a k₁ e k₁ b* of Dr. Laws.

is small, as in the midship bottom plating of a ship, the tensile stress due to end tension is not a large proportion of the stress due to bending. If the deflection is appreciable as in a main water tight transverse bulkhead, the tensile stress is very important.

Dr. Laws has taken the simplest case which will lead to mathematical treatment in which I_1 is uniform for a length r of the span. I would suggest to him that he should analyse the effect of varying r in relation to the span. In the examples put forward to Lloyd's Register, already referred to, I_1 was not uniform, so that the solution of the problem involved somewhat laborious plotting and graphic integration, but Mr. J. C. M. Wilson and I have examined the effect of varying r and find that there seems to be a particular value of r which, if increased, will increase the end stress due to bending. I hope the suggested mathematical investigation will confirm this.

With regard to Dr. Laws practical application of his investigation, I am afraid he is gravely in error. I say gravely, because the diagram in which he has summarised his conclusions in a graphical form (Fig. 6), which will appeal at once to the practical shipbuilder who has not the time to examine the paper closely is, if I have read it correctly, surely very misleading.

The panel *a b c d* purports to be a portion of a large surface of plating resting on a rigid meshwork forming panels such as *a b c d*. The curve *a k b* represents the principal stress along the long side *a b* of the panel. The value of n for this panel is about 5·5 and $f(n)$ of Dr. Laws' formula I estimate to be 0·45. A rigid boundary *e f* is introduced parallel to the short side, altering the value of n to 2·75 and $f(n)$ to 0·35. Since r the width of the panel, is unaltered, the maximum ordinate of the curve *a k b* will bear to the maximum ordinate of *a k e* the ratio of 0·45 to 0·35, or 9 to 7. Dr. Laws' curves show a ratio, so near as I can measure, of 3 to 1, thus exaggerating (it is more than exaggerating) the benefit of dividing that particular panel by a rigid boundary. The maximum stress in the long side *a e* is thus 0·8, not 0·33, of that in the long side *a b*.

This diagram may have led to Dr. Laws' statement that on theoretical grounds free-ended stiffeners should not be used. Theory tells us that free-ended stiffeners reduce the maximum stress, though not so much as rigid boundaries. Theory does not tell us that free-ended stiffeners should not be used, but that they can be successfully used. It does not tell us they are much less costly to provide than rigid boundaries. I cannot think Dr. Laws' views will be those of the registration societies.

As a result of the discussion of this problem with Lloyd's Register, commencing in March last, the writer and Mr. D. B. Gebbie—who have together protected a system of ship construction which it is hoped will shortly be described in the press—are undertaking experiments which will, it is hoped, elucidate some of the points which theory cannot settle. The experiments will be conducted to meet the requirements of the registration societies. Proposals for the actual test structure have already been for some time before Lloyd's Register and the British Corporation, and are still under discussion.

Yours faithfully,

T. B. ABELL.

The University of Liverpool, School of Naval Architecture, September 12, 1921.

THE LINKING-UP OF THE SMALL WATER POWERS IN SCOTLAND.*

By Professor F. G. BAILY, M.A., F.R.S.E., M.I.E.E.

SCOTLAND is full of streams and rivers, the average height of the country is considerable, and the rainfall generous. The theoretical water power calculated from these sources runs into many millions. But for the most part the rivers have too gradual a fall, and the streams of the steeper ground too little water, to permit of any great concentration of water power at any one place. Hence most of the power runs to waste, only a few favourable places affording both volume of water and rapid fall. A scheme is proposed to utilise the small rapid streams and waterfalls of the high uplands, and the rivers of the long gently-sloping valleys, by numerous small hydro-electric stations, so that the rainfall will pass through a succession of turbines in its passage from the gathering ground to the sea, and yield up a fair proportion of its total energy. For this purpose, the stations must be small, generally from 50 h.p. to 300 h.p., in order to avoid the costly engineering work of large dams and long lades and pipe lines; they must operate automatically to reduce cost of superintendence, and they must be simple and robust.

Each turbine will drive a dynamo of the kind known as an induction generator, which is a three-phase squirrel-cage motor, driven at a speed slightly above that at which it runs as a motor. Without any control or adjustment this machine will supply electric current to the mains in proportion to the water power available, and thus, up to the limits of the output of the turbine, it converts all the power of the stream, be it small or large. The starting up is so simple that it may be controlled from a distant central point, and once started no further care is needed. The general arrangement consists in a set of electric mains running out from a large town with a steam-driven central supply station, following the course of the river and branching at its tributaries, until the distance and the smallness of the streams render further extension uneconomical. At all suitable points, these small stations are erected, merely a hut with turbine and dynamo, feeding their quotum of power into the system. The steeper parts will have short lades and pipes to the turbines, but in the valleys, a succession of small dams will be built, and the turbine house will be a part of the dam, running with the head of water of the dam, unless the ground favours the construction of a lade in addition. These dams also serve to store water in times of drought, by the shutting down of the turbines from the main station during the hours of light load. As fluctuations of head make no difference to the dynamo beyond changing the amount of power it is able to deliver, considerable use can be made of these dams without any supervision.

Superintendence may be reduced to periodic visits round the area to see that all is well, and to clear the strainers of the intake water. Wear and tear of turbine and dynamo are extremely small, as neither has any rubbing surfaces except the bearings of the main shaft.

The central station will require some special provision, for it supplies the magnetising current for all the small dynamos. But even this may be provided by water-driven alternators set at some more central point. These would require an attendant, who would also be suitably placed for the control of the upland stations.

In all water-power schemes, the chief difficulty is the irregularity of the water, and usually this can only be avoided by making a huge reservoir, or by using only a fraction of the average power. By linking up with a large system, times of drought will make calls on the steam engines, but through the heavy winter load the water power will be at its best. Any other possible sources, such as the tidal force in estuaries, may be linked up as well, and the various fluctuations of these, and the changes of the load, will tend to average out to some extent, the balance being taken by the central station.

The electric mains not only form collectors of power, but they are equally valuable as distributors. All the farms, villages and small towns in the area will link on to the system, and much of the power may be used before the town is reached, while the central station ensures regularity of supply. The district will be opened up, and many facilities for industry will be afforded.

The essential features in this scheme are the cheapness and simplicity of the small stations, the low cost of supervision, and the large proportion of the possible power that is utilised. It may be developed gradually, for even a few stations in an area are helpful, and successive additions do not disturb those in existence. Hence, while the complete plan will be of great magnitude, the financial commitment at the beginning is small until success is assured.

I am indebted to Mr. D. S. Munro, of Edinburgh, for the idea of collecting the water power of scattered streams and long rivers by small units of power, and to Dr. Steinmetz, of America, for the use of the induction generator as a feeder to a supply system. The combination of the two seemed to me the best solution of the problem, and, in the working out of the details, its advantages have manifested themselves.

* Paper read before Section G of the British Association at Edinburgh, September 9, 1921.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Pessimists who seek to maintain that trade locally is going from bad to worse are confounded by the simple fact that since the coal strike 30,000 workless have been absorbed in the staple industries of Sheffield. This leaves the city's total unemployed at 40,000, which number is being reduced at the rate of about 1,000 per week. While recovery in the engineering section is not being made at the speed which many anticipated, the undertone appears to be more settled, with fairly definite prospects of improvement by the end of the year. Several producers of heavy plant have slightly increased their staffs to expedite arrears of orders placed principally by the Colonies, among whom Australia is the best buyer. The current demand for railway tyres, axles and springs is on a limited scale for shipment, and is disappointing so far as home requirements are concerned. On the other hand, business appears to be looking up in wagons and locomotives, and a healthy call is maintained for textile machinery and machine tools for shipment. While the crucible trade is distinctly patchy, leading firms are to be found where the full complement of furnaces has again been put into commission, and where output is on a normal basis. Whatever may be the future of American trade, current deliveries are on a large scale. Sheffield's business with the Continent in special steels is hampered as much by import restrictions as by price considerations. The automobile and agricultural industries are taking only minor quantities of special steels, bars and castings, but show a livelier interest in revised quotations. Recently-established businesses dealing in the mass production of such hand tools as pliers and pincers, and in implement blanks, are feeling the force of the German revival considerably, especially where large stocks of high-priced materials remain on hand. Tool-makers are canvassing the market keenly for new business, and in some cases are buying semi-finished material from Wales, delivered at considerably lower prices than are quoted locally. Bedrock values have apparently not yet been reached in raw and semi-finished materials. Bessemer mixed numbers of pig-iron are arriving in South Yorkshire from the West Coast at a reduction of 10*s.* per ton on last week's quotation, the current level being round about 7*l.* 15*s.* No further revision is notified by the South Yorkshire Bar Iron Association, but Crown bars are available at 16*l.* net.

South Yorkshire Coal Trade.—Owing to the further congestion at the pits and the consequent partial suspension of production, big tonnages of smalls are available at a record figure of 5*s.* per ton. This is considerably below the official quotation for August, 1914, which stood at 8*s.* to 9*s.* The market is easing in other directions, though by no means to the same extent. Despite the scarcity of business in house coal, best qualities are maintained at their former level, with a reduction of 1*s.* to 2*s.* in the case of inferior grades. Manufacturing fuel is 2*s.* to 3*s.* per ton cheaper, and slacks have been marked down an average of 2*s.* per ton as a further reduction. Best steam hards are going away fairly well. An improvement is noticeable in shipments. Cobbles and nuts are still weak owing to the fact that the large consumers have not yet recommenced full-time operations. No considerable improvement is looked for in the demand for slacks until the coke ovens are recommissioned. Cokes are still on the quiet side. The recent reduction in prices has not brought any sustained improvement in business. Quotations: Best branch handpicked, 40*s.* to 41*s.*; Barnsley best Silkstone, 40*s.* to 41*s.*; Derbyshire best brights, 35*s.* to 36*s.*; Derbyshire best house coal, 34*s.* 6*d.* to 35*s.*; Derbyshire best large nuts, 32*s.* to 33*s.*; Derbyshire small nuts, 29*s.* to 30*s.*; Yorkshire hards, 34*s.* to 35*s.*; Derbyshire hards, 33*s.* to 34*s.*; rough slacks, 17*s.* to 18*s.*; nutty slacks, 16*s.* to 17*s.*; smalls, 5*s.* to 10*s.*

TRADE WITH SOUTH AFRICA.—Mr. W. G. Wickham, His Majesty's Senior Trade Commissioner in South Africa, is engaged on an official tour of this country for the purpose of discussing with firms the possibilities and conditions of United Kingdom trade with the Union of South Africa. The first part of his tour includes the following towns: Leicester, September 19 to 21; Nottingham, September 22 to 23; Sheffield, September 28 to 30; Leeds, October 3 to 5; Bradford, October 6 to 11. Firms in these centres desiring to interview Mr. Wickham should communicate immediately with the secretary of their local Chamber of Commerce.

THE FARADAY SOCIETY.—A general discussion on "Catalysis with Special Reference to Newer Theories of Chemical Action" will be held under the auspices of the Faraday Society, on Wednesday, September 28, at the Institution of Electrical Engineers, Victoria Embankment, W.C. 2. The discussion will be divided into two parts: Part I beginning at 4.30 p.m., will deal with the "Radiation Theory of Chemical Action," and it will be opened by Professor J. Perrin, of Paris. The second portion of the discussion will concern itself with "Heterogeneous Reactions," and it will be opened by Professor Irving Langmuir, chief research chemist to the General Electric Company, U.S.A. It is expected that Professor Arrhenius and Professor Victor Henri will also be present, and among others who will contribute to the discussion are Professor E. C. C. Baly, Professor F. G. Donnan, Professor W. C. McC. Lewis, Professor A. Lindemann, Professor A. W. Porter and Dr. E. K. Rideal. Fellows of the Chemical Society are invited to attend this meeting. Others interested in the subject may obtain tickets of admission from the Secretary of the Faraday Society, 10, Essex-street, London, W.C. 2.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Quietness continues to characterise the pig-iron market. Rather more inquiry is said to be circulating, but actual transactions are few and small. So far as No. 3 G.M.B. Cleveland pig-iron is concerned, scarcity is still very pronounced, only one firm at present being engaged in production, and what stocks there are, having already been disposed of, but customers are now definitely stating that they will not pay beyond a certain figure. There is practically no foreign trade passing, but some home business in No. 3 has been put through at 125*s.* which may now be regarded as an outside figure. As a matter of fact orders have been placed at a lower price. Foundry 4 is quite plentiful and is offered freely at 119*s.* There are large stocks of the inferior grades which makers would much like to reduce by selling No. 4 forge, and mottled at 117*s.* 6*d.*, and white iron at 115*s.*

Hematite.—Supply of East Coast hematite is little more than ample for needs. A few fairly good home sales are reported, but export transactions are within very narrow limits. For home consumption, No. 1 is 142*s.* 6*d.*, and Nos. 2 and 3 are 140*s.* Makers are very keen to secure orders for despatch to foreign destinations, and for such business are ready enough to accept 137*s.* 6*d.* for No. 1 and 135*s.* for mixed Nos.

Foreign Ore.—There is stagnation in foreign ore, and prospect of movement in the direction of opening out negotiations of any consequence, is remote, as consumers have heavy stocks, and large deliveries to take up against old contracts much overdue for completion.

Coke.—Coke keeps too dear to admit of much buying by local users. They consider that the maximum price of Durham blast furnace description, delivered, should be 30*s.*, whereas sellers are not disposed to name less than 35*s.*

Manufactured Iron and Steel.—Very little new is ascertainable concerning finished iron and steel. A few specifications have recently been given out, but buyers continue to pursue a cautious policy, believing that further fall in prices is at hand. Orders for export can be placed at less than the following quotations for home purposes:—Common iron bars, 16*l.*; marked bars, 2*l.*; iron strip, 17*l.* 10*s.*; steel billets (medium), 10*l.* 10*s.*; steel billets (hard), 11*l.*; steel boiler plates, 19*l.*; steel ship, bridge and boiler plates, 14*l.*; steel angles and joists, 13*l.* 10*s.*; steel hoops, 14*l.*; tees, 14*l.*; rounds and squares, 12*l.*; flats, 14*l.*; heavy sections of steel rails, 14*l.*; fish plates, and sleepers, 19*l.*; black sheets, 17*l.*; and corrugated galvanised sheets, 20*l.* 10*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

The Trade Position.—The conditions which have been prevailing in trade circles throughout the country for some considerable time show little sign of improvement. It will be a long time before the effects of the coal strike have passed away and business in this country gets back to better times, but another very important cause of to-day's depression is the generally unsettled state of the markets of the world, for other countries are also passing through rather an awkward period. Prices all round are too high and buyers are most unwilling to give out orders while of opinion that lower levels must prevail before long. This is not only the case in iron and steel trades, but in nearly all other industries, and dealings are thereby very restricted. The shipbuilding trade is quiet and engineering firms report that there is very little doing, but rivet, bolt and nut makers are better employed. Despite everything a more hopeful feeling is fairly general, but when there are so many thousands of unemployed in every area one wonders when that feeling is going to be translated into actual business.

Scottish Steel Trade.—No change is visible in the Scottish steel trade and orders come in so slowly that managements can arrange very little ahead. Both ship plates and sectional material are in poor demand and there is no pressure for delivery. Producers of black sheets report little increase in business since prices were reduced, and it is feared that a further cut will be necessary to induce buying. The general inquiry, while better, does not inspire confidence, and no decided improvement is anticipated until home prices come nearer to those named by the Continental makers.

Scottish Malleable Iron Trade.—The malleable iron makers in the West of Scotland are very badly off for work and hand-to-mouth conditions still prevail. Cost of production continues very high, and it is difficult for makers to bring down prices if they are to secure business on a profitable basis. The Continental material is coming in steadily at prices which cannot be looked at by the local firms.

Scottish Pig-Iron Trade.—The Scottish ironmasters report little alteration in the state of trade, and although the general tone is a bit brighter there has not been much increase in demand. Several more furnaces are in blast on ordinary qualities of pig-iron and the quantity of foundry sorts now available is more than equal to the demand. Hematite is moving very slowly and old stocks are sufficient to meet present requirements. Business is very quiet, and little in the way of expansion can be looked for until fuel gets cheaper to enable prices to ease further. The following may be taken as the current prices:—No. 1 foundry iron, 8*l.* 5*s.* per ton; No. 3, 8*l.* per ton, free on trucks at producers' works; and hematite, 7*l.* 15*s.* per ton, delivered at the steel works.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—There are signs that gradually South Wales colliery owners and coal exporters are regaining markets lost during the war and the period of control. This is evidenced by the fact that foreign cargo exports of coal in August, at 1,395,000 tons, established a record for any month this year, and compared with 952,000 tons in March, 862,000 tons in February and 924,000 tons in January. Compared with the pre-war rate of exports there is, however, much leeway to be made up for in August shipments were at the rate of 18,000,000 tons per annum, compared with 30,000,000 tons in 1913. In August, exports to France totalled 423,000 tons, to Italy 203,000 tons, to South America 161,000 tons, to Spain 110,000 tons, to Portugal 89,000 tons, to Greece 16,000 tons, to British coaling depots 162,000 tons and to other countries 231,000 tons. Steamer charterings, too, in August were the highest for any month of the year. For Cardiff loading they totalled 972,000 tons, compared with 655,000 tons in July, and 562,000 tons in February, and for Swansea shipment 131,000 tons against 107,000 tons in July, and 55,000 tons in January. The average f.o.b. price of large steam coal shipped from Cardiff in August worked out at 43*s.* 6*d.* per ton, compared with 45*s.* 9*d.* in July, and 74*s.* 11*d.* in January, and for steam small 21*s.* 3*d.* against 21*s.* 7*d.* in July and 48*s.* 7*d.* in January, a considerable reduction. Small steams shipped from Swansea in August averaged 24*s.* 6*d.*, compared with 29*s.* 9*d.* in March and large steams 40*s.* 7*d.*, against 76*s.* 4*d.* in January. The current position of the market is unchanged compared with a week ago. The demand is confined to best large and small steams, the inquiries for other grades being practically nil. Colliery stoppages are frequent and numerous because of congestion at the docks and on the railways, which results in a shortage of wagons. For best large steam 32*s.* 6*d.* is asked, but business is taking place at 1*s.* to 2*s.* less, while for best steam smalls the price is round 19*s.*

Iron and Steel.—Though the general demand for tin plates shows a little expansion, prices remain on the easy side with standard boxes from 21*s.* 6*d.* to 23*s.* Foreign steel continues to be landed in South Wales at 7*l.* to 7*l.* 10*s.* per ton, compared with the Siemen's Association minimum price of 8*l.* 10*s.*, though outside makers are offering Welsh bars at 8*l.* There is a better inquiry for galvanised sheets, and makers are adhering to 20*l.* to 20*l.* 10*s.* for 24-gauge corrugateds in bundles. Scrap is plentiful, with heavy scrap for furnace use at 60*s.* to 70*s.* and heavy cast-iron scrap 4*l.* 5*s.* to 4*l.* 10*s.*

ROYAL AERONAUTICAL SOCIETY.—The session will be opened by the following two papers: October 6, "Some Notes on Aeroplanes in Tropical Countries," by Air-Commodore H. R. M. Brooke-Popham; October 20, "The Langley Machine and the Hammondsport Trials," by Mr. Griffith Brewer.

UNIVERSITY OF MANCHESTER.—The prospectus of university courses in the Municipal College of Technology, Manchester, for the session 1921–22, has now been issued. It gives a history of the college, a description of the buildings, the names of the officials and staffs, regulations, time-tables, syllabuses and awards.

THE ROYAL SANITARY INSTITUTE.—A meeting is to be held on Friday and Saturday, October 7 and 8, in the Town Hall, Stoke-on-Trent, when discussions will take place on "Activated Sludge," and on "Smoke Pollution of the Atmosphere in the Potteries." Visits will be made to various works and establishments in the district. Further information can be obtained from the Secretary, 90, Buckingham Palace-road, S.W. 1.

LANTERN SLIDES FOR ENGINEERING LECTURES.—Messrs. Tangyes, Limited, Cornwall Works, Birmingham, have available for loan to engineering lecturers and technical instructors a large selection of lantern slides illustrating the products of the firm, and engineering matters of historical interest. The list, which contains 340 slides, covers gas engines, producers, oil engines, pumps, hydraulic machinery, machine tools, &c., will be forwarded free on application to Messrs. Tangyes. Printed copies of papers dealing with the firm's machinery are also available for lecturers.

COMMERCIAL MOTOR VEHICLE EXHIBITION AT OLYMPIA.—The Fifth International Exhibition of Commercial Motor Vehicles, organised by the Society of Motor Manufacturers and Traders, will be held at Olympia from October 14 to 22 next. The Exhibition will include vehicles driven by petrol, steam and electricity, designed for the transport of goods or passengers, or for general utility purposes. Lorries, charabancs, fire engines, ambulances, tipping wagons, road-sweepers, &c., are all within the scope of the exhibition, which will remain open daily from 11 a.m. to 8 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS.—This association have formed a new Student Section of members. The object of the new section is to enable engineering trade apprentices and students to extend their general knowledge of the various sections of engineering, also—and this, in our opinion, is a most praiseworthy enterprise—to provide them with opportunities for the making of social friendships and of acquiring powers of expression as a result of reading papers and contributing to the debates thereon. A programme has been arranged for the opening session, commencing in October, in order to initiate the section and so enable the students to organise themselves.

NOTICES OF MEETINGS.

THE INSTITUTION OF PRODUCTION ENGINEERS.—Saturday, September 17, at 7 p.m., at the Institution of Mechanical Engineers, Storey's Gate, London, S.W. Paper by Mr. J. D. Scaife, Member of Council, on "The Manufacture of Ball and Roller Bearings," illustrated by lantern slides.

THE INSTITUTE OF METALS.—Tuesday, September 20, from 2.30 p.m. to 8 p.m., the office of the hon. local secretary will be open at the Municipal Technical School, Suffolk-street, Birmingham. Wednesday, September 21, from 10 a.m. to 12.40 p.m., General Meeting of members in the Examination Hall, Municipal Technical School, Suffolk-street; the Lord Mayor of Birmingham, Alderman William A. Cadbury, will open the meeting with a brief address of welcome; papers will be presented and discussed. At 12.50 p.m. for 1 p.m., members assemble at the Grosvenor Rooms, Grand Hotel, Colmore-row, for luncheon, by invitation of the Metal Trades Associations, viz., Brass and Copper Tube, Brass Wire, Brassfounders' Employers, Brazed Brass Tube, British Aluminium Holloware Manufacturers', Cold Rolled Brass and Copper, and Nickel Silver Associations. Then follow various receptions. Thursday, September 22, 10 a.m. to 12.40 p.m., General Meeting of Members; papers will be presented and discussed as time permits; receptions in the afternoon and evening. Friday, September 23, motor excursion to Kenilworth, Warwick and Stratford. The following is a list of the papers that are expected to be submitted in the order given: (1) Professor A. A. Read (Cardiff) and Mr. R. H. Greaves (Woolwich), on "The Properties of Some Nickel-Aluminium-Copper Alloys"; (2) Mr. R. T. Rolfe (Bedford), on "The Effect of Increasing Proportions of Lead upon the Properties of Admiralty Gun-metal"; (3) Mr. R. Genders (Woolwich), Note on "The Casting of Brass Ingots"; (4) Mr. T. G. Bamford (Birmingham), on "The Density of the Zinc-Copper Alloys"; (5) Mr. F. Johnson (Birmingham), on "Experiments in the Working and Annealing of Copper"; (6) Mr. W. E. Alkins (Manchester) and Mr. W. Cartwright (Buxton), on "The Effects of Progressive Cold Drawing upon Some of the Physical Properties of Low-Tin Bronze"; (7) Mr. R. Genders (Woolwich), on "The Extrusion Defect"; (8) Mr. F. S. Tritton (Teddington), on "The Use of the Sclerescope on Light Specimens of Metals"; (9) Mr. D. H. Ingall (Birmingham), on "The Annealing of Rolled Zinc"; (10) Mr. D. Hanson (Teddington) and Miss M. L. V. Gayler (Teddington), on "The Constitution and Age-Hardening of the Alloys of Aluminium with Magnesium and Silicon"; (11) Mr. F. Adcock (Ipswich), on "The Electrolytic Etching of Metals"; (12) Mr. S. Beckinsale (London), Note on "Electron" (the high magnesium alloy).

WEST BROMWICH ENGINEERS SOCIETY.—Friday, September 23, at 7.30 p.m., at the Technical School. Paper: "The Production of Iron," by Mr. C. E. Roberts, B.A., B.Sc. (of Messrs. N. Hingley and Sons, Limited, Old Hill, Staffordshire). Lantern and discussion.

ASSOCIATION OF RAILWAY COMPANIES SIGNAL SUPERINTENDENTS AND SIGNAL ENGINEERS.—The sixty-third conference of the association will be held at the Railway Clearing House, London, on Thursday, the 29th inst.

BALANCING ROTARY BODIES.—The Committee of the Shipping and Engineering Exhibition have arranged for a lecture to be delivered on this subject at the exhibition on the 27th inst., at 3 p.m. Any suggestions or questions sent to Engineer-Captain J. E. Mortimer, 34, Victoria-street (3rd floor), Westminster, S.W.1, will be welcome.

THE BRITISH COMMERCIAL GAS ASSOCIATION.—The tenth annual conference of this Association, whose offices are at 30, Grosvenor Gardens, S.W. 1, is to be held in the Royal Technical College, George-street, Glasgow, on Tuesday and Wednesday, the 27th and 28th inst., under the presidency of Mr. D. Milne Watson, M.A., LL.B. Papers will be read and discussed on "The Hygiene of Gas Heating," "The Prevention of Smoke Pollution," "Industrial Uses of Coal Gas," "Gaseous Fuel in the Shipbuilding World," "A Thousand and One Uses for Gas," "Production, Distribution and Uses of Gas Coke." The proceedings will be opened with a presidential address by Mr. D. Milne Watson. Further particulars on the conference can be obtained from the association.

CATALYSIS WITH SPECIAL REFERENCE TO NEWER THEORIES OF CHEMICAL ACTION.—A general discussion on this subject will be held under the auspices of the Faraday Society on Wednesday, September 28, at the Institution of Electrical Engineers, Victoria-embankment, W.C.2. The discussion will be divided into two parts. Part I, beginning at 4.30 p.m., will deal with the "Radiation Theory of Chemical Action," and will be opened by Professor J. Perrin, of Paris. The second portion of the discussion will concern itself with "Heterogeneous Reactions," and will be opened by Professor Irving Langmuir, Chief Research Chemist to the General Electric Company, U.S.A. It is expected that Professor Arrhenius and Professor Victor Henri will also be present, and among others who will contribute to the discussion are Professor E. C. C. Baly, Professor F. G. Donnan, Professor W. C. McC. Lewis, Professor A. Lindemann, Professor A. W. Porter, and Dr. E. K. Rideal. Fellows of the Chemical Society are invited to attend this meeting. Others interested in the subject may obtain tickets of admission from the secretary of the Faraday Society, 10, Essex-street, W.C. 2.

UNIVERSAL TOOL AND CUTTER GRINDER AT OLYMPIA.

CONSTRUCTED BY MESSRS. TANGENT TOOLS, KEYNSHAM, SOMERSETSHIRE.

(*For Description, see Page* 414.)

FIG. 14. GRINDING LATHE TOOL.

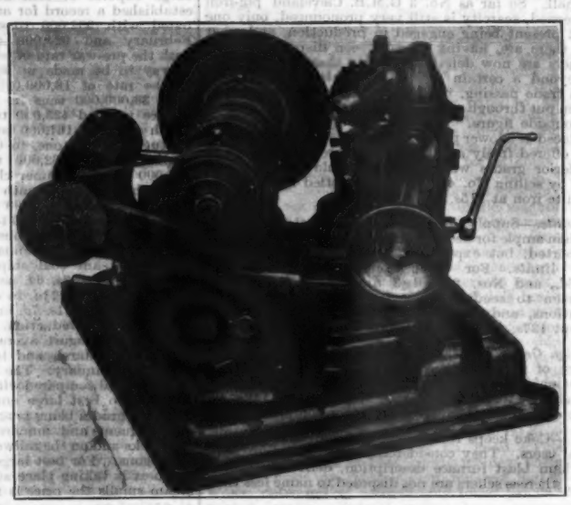


FIG. 15. GRINDING SINGLE ANGLE CUTTER.

FIG. 16. GRINDING SPIRAL ANGLE CUTTER.

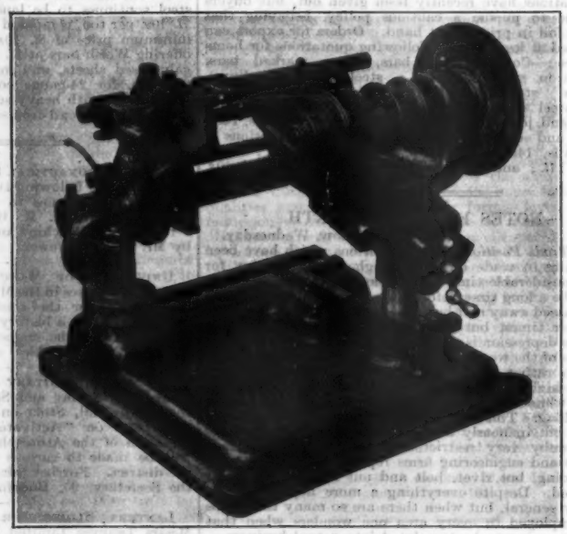


FIG. 17. GRINDING WOODRUFF CUTTER.

FIG. 18. GRINDING DOUBLE ANGLE CUTTER.

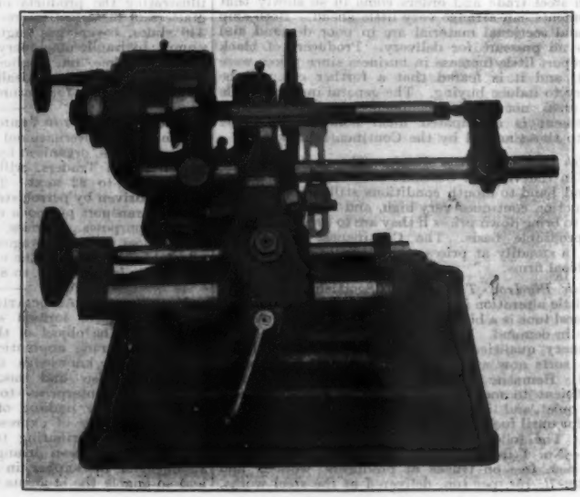


FIG. 19. GRINDING PARALLEL REAMER.

THE PORTOBELLO ELECTRIC POWER STATION OF THE EDINBURGH CORPORATION.

CONSTRUCTED TO THE DESIGNS OF MESSRS. KENNEDY AND DONKIN, CONSULTING ENGINEERS, WESTMINSTER.

(For Description, see Page 422)

Fig. 3.

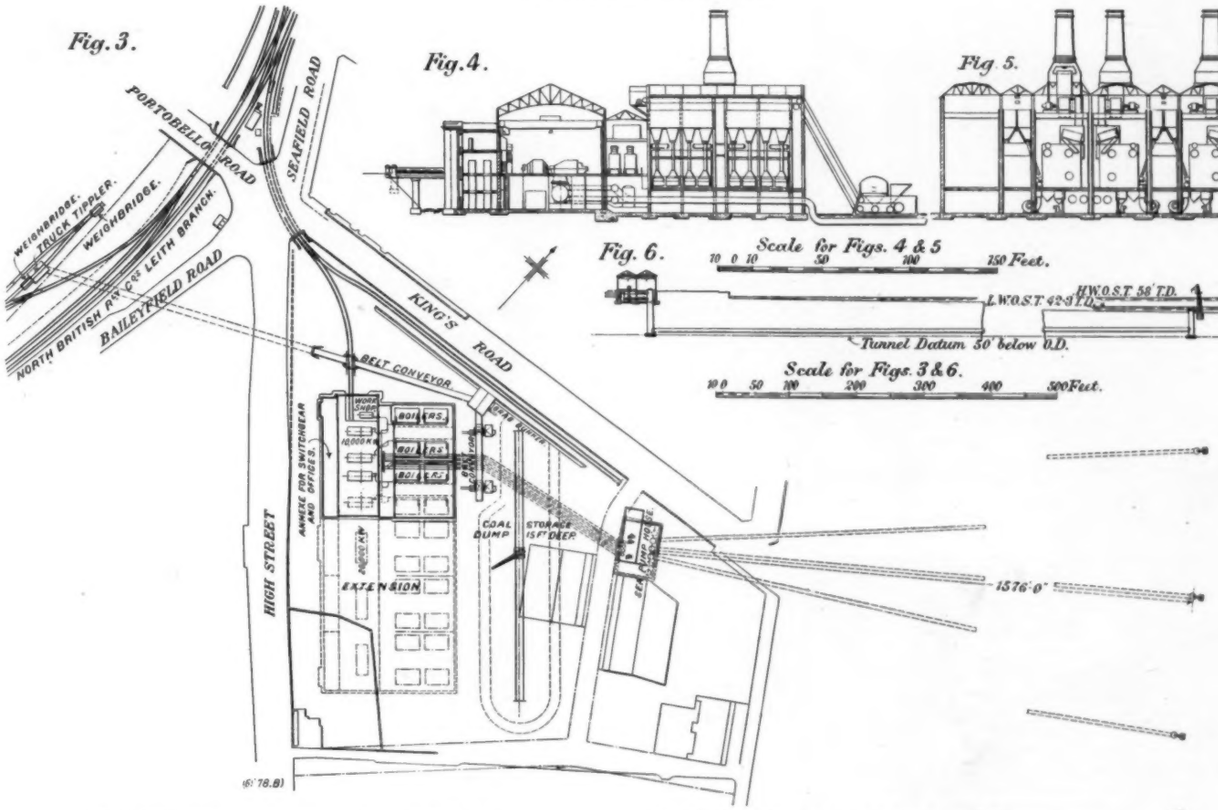


Fig. 4.

Fig. 5.

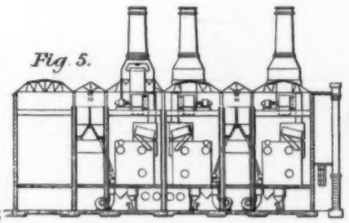


Fig. 6.

Fig. 7. SECTIONAL ELEVATION B.B OF BOILER N°1.

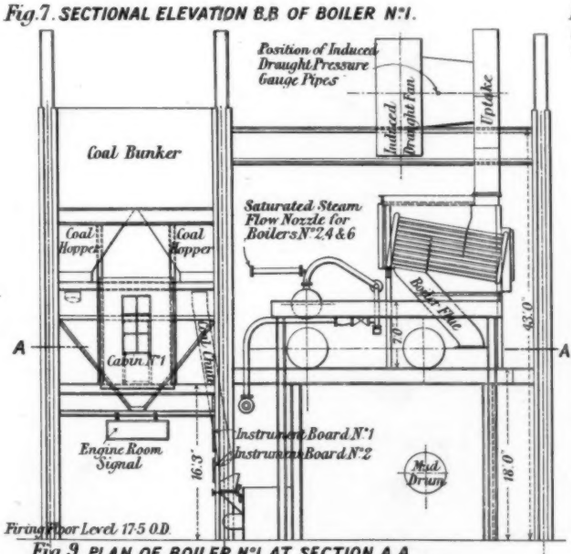


Fig. 8. SECTIONAL ELEVATION OF BOILER N°1.

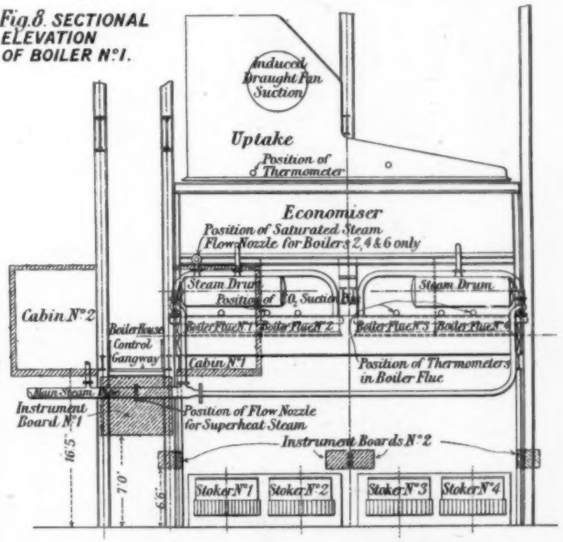


Fig. 9. PLAN OF BOILER N°1 AT SECTION A.A.

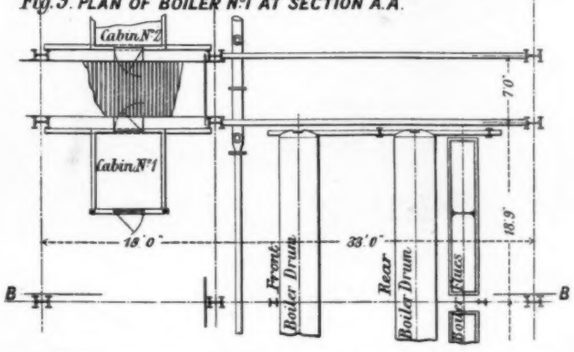
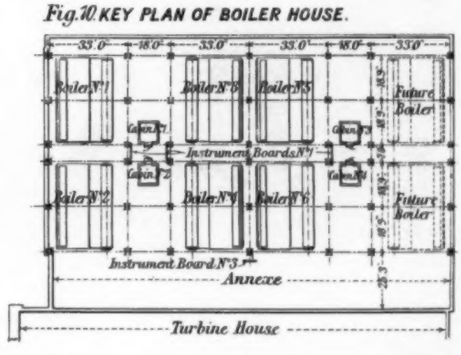


Fig. 10. KEY PLAN OF BOILER HOUSE.



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(*For Description, see Page* 422.)

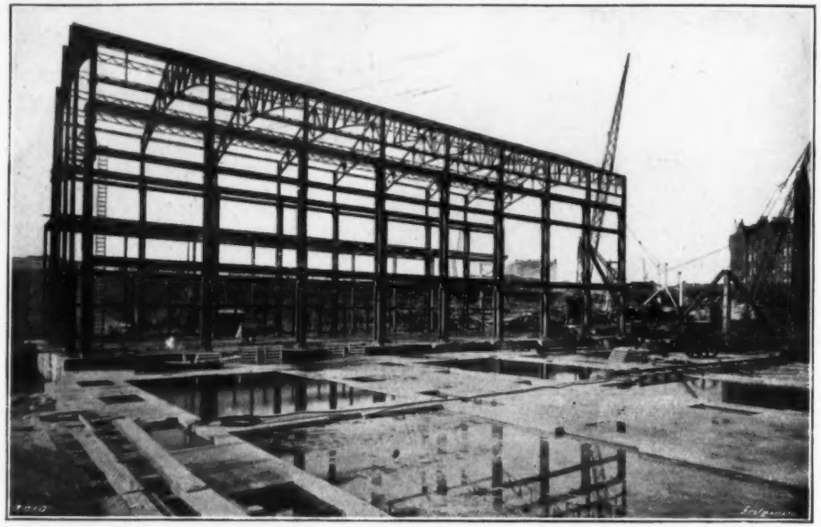

FIG. 11. FRAMEWORK OF GENERATOR BUILDING.

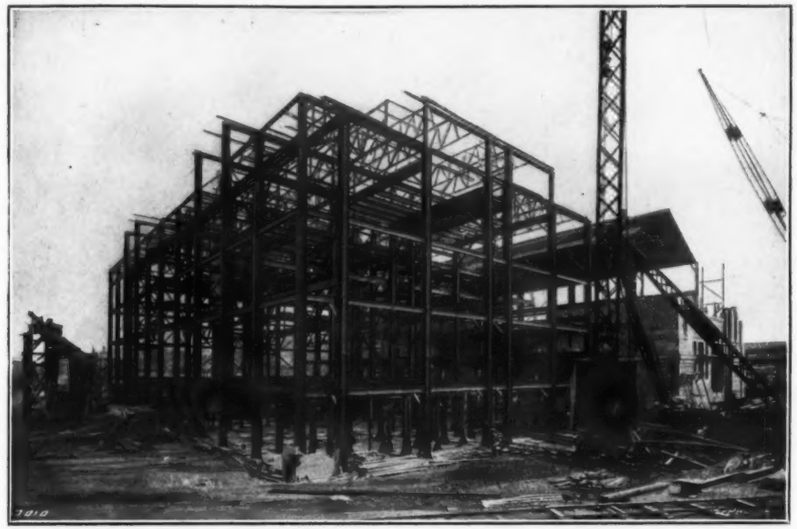

FIG. 12. FRAMEWORK OF BOILER-HOUSE BUILDING.

FIG. 13. INTERIOR OF GENERATOR BUILDING.

FIG. 14. WORKINGS AT THE LANDSHAFTS AND VENTILATING DUCT.

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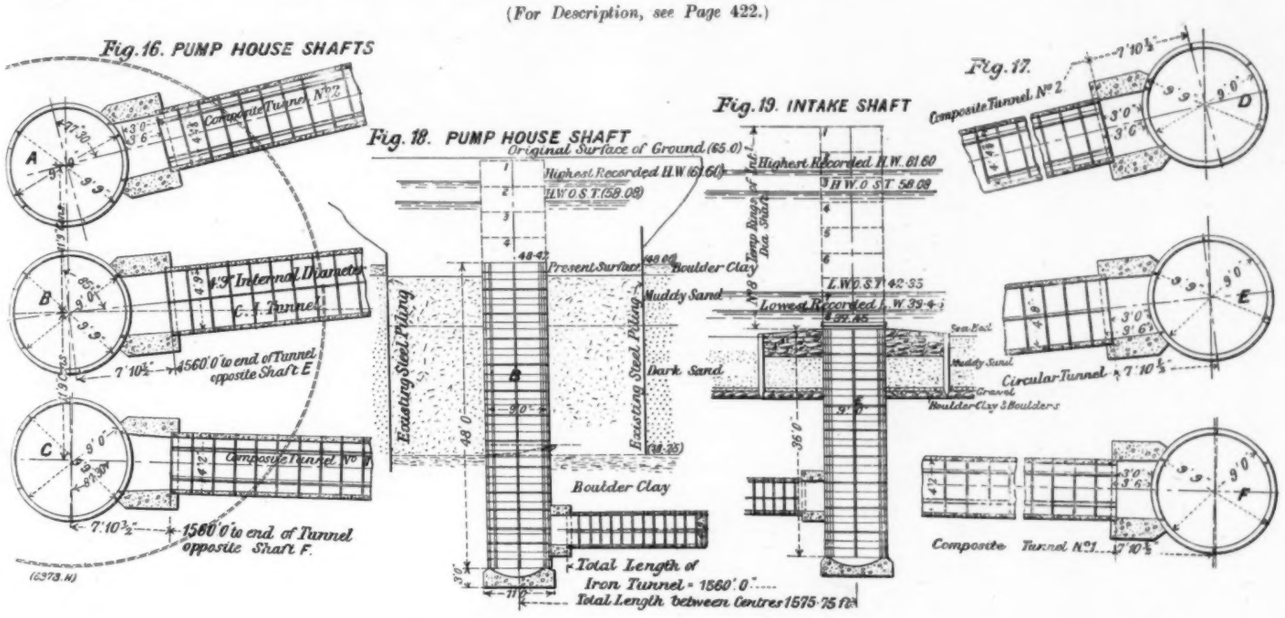

FIG. 20. INTERIOR OF TUNNEL.

FIG. 21. STARTING TO LAUNCH STEEL CYLINDER.

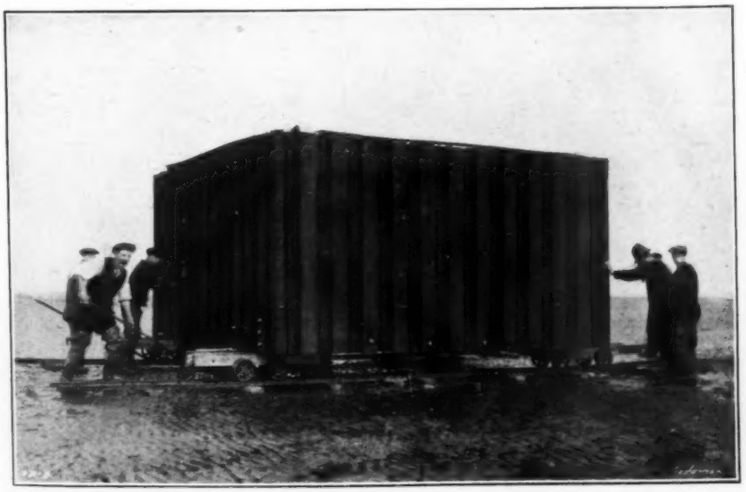

FIG. 22. LAUNCHING STEEL PILE BOX.

FIG. 23. TOP OF ONE OF THE SHAFTS.

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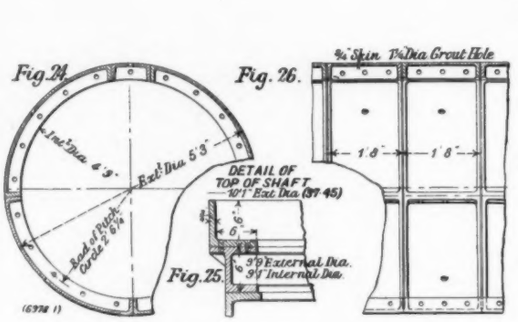

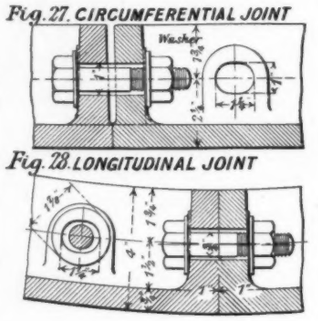

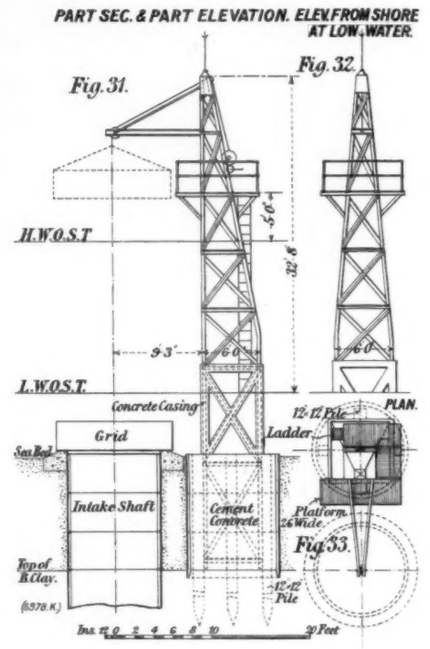

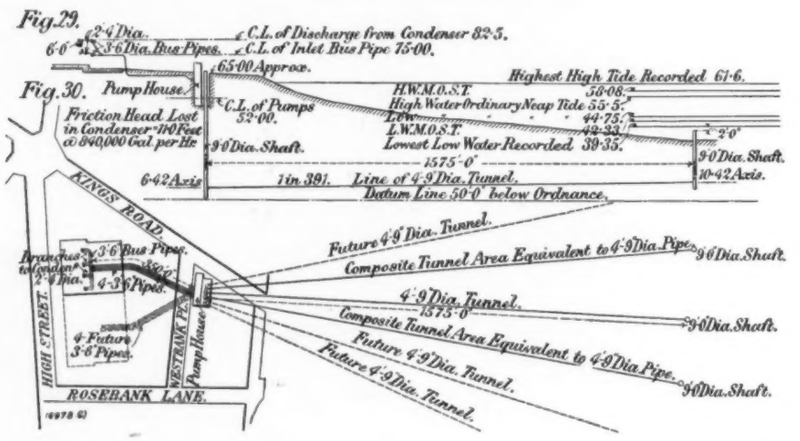

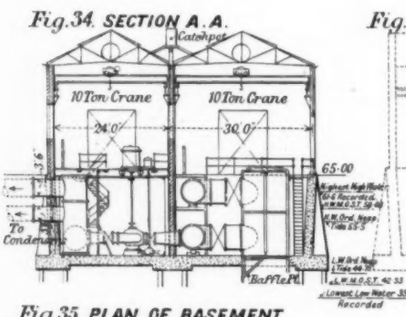

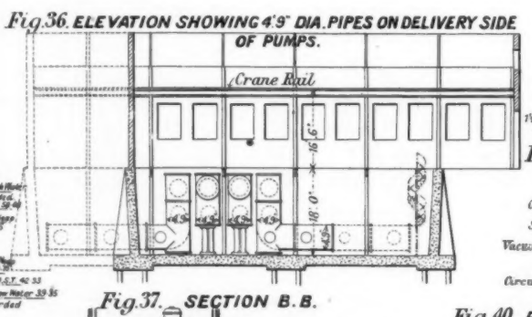

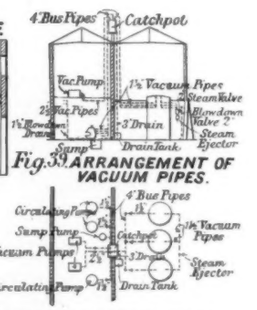

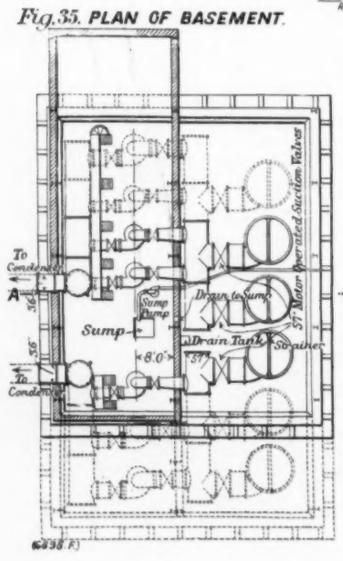

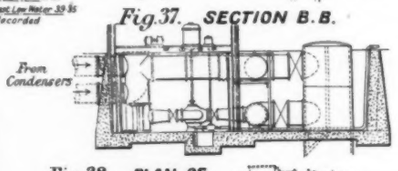

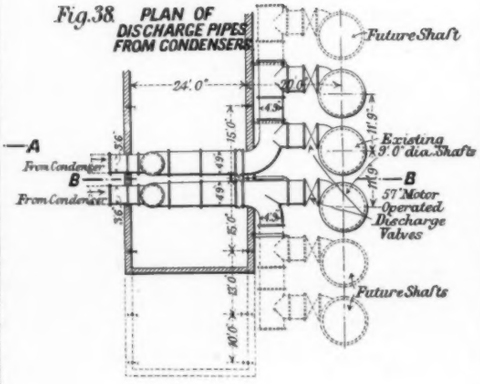

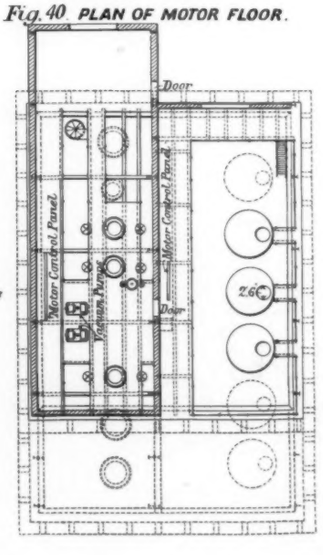

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With Four One-Page Plates of the PORTOBELLO ELECTRIC POWER STATION OF THE EDINBURGH CORPORATION.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 411.

ENGINEERING.

FRIDAY, SEPTEMBER 16, 1921.

THE GROWING IMPORTANCE OF THE SMALLER CLASSES OF ENGINEERING.

ONE of the most striking developments of modern times is the rapid growth in importance of the smaller classes of engineering work. This tendency can perhaps be best seen in the case of prime movers, though it applies also to many other classes of work. It is not so many years ago that the production of power by mechanical means was mainly confined to relatively large units. Ships and trains were driven by steam, and steam was used for the driving of stationary machinery of all kinds. In fact, for the production of power on a large scale steam was fairly universal in ordinary cases. To a certain extent small steam engines were used for marine, stationary and agricultural work, but the greater part of the production of power was provided by other means. Horses provided power for the roads, sails and oars for small boats, &c. In fact, the absence of small prime movers entailed a great deal of manual work. During the last twenty years there has been a great change; and mechanical power can now be used for an enormous number of purposes for which it was formerly practically unavailable. How far this development depends on demand and how much on supply cannot be discussed here, each being dependent on the other.

The most obvious development is, of course, in connection with road travel, and this has been, largely at all events, dependent on the development of the petrol motor. This provides a prime mover which can be made in a simple and practicable form in units as small as 1 h.p., and with a weight of a few pounds per horse-power. Being simple, the petrol engine is a very cheap prime mover to produce, which is a matter of great importance in any machine that is to come into general use. The result of the great application of motor progression to the roads is that motor-propelled vehicles of various kinds largely take the place of walking, cycling, and riding, and also that the use of the road is extending enormously.

In marine work a similar change is taking place. Small marine steam engines of sufficiently substantial construction were relatively heavy and took up a good deal of room. They were also expensive. Hence their application was very limited. With the advent of the petrol motor all this changed. It is now possible to obtain engines of far less weight than was thought practicable some years ago, and they can be made of very small powers. Further they are of the simplest construction and very cheap. The result has been an enormous extension of the use of power for the smaller sizes of boats. Small motors are being installed in large numbers, both as auxiliaries in the moderate-sized sailing boats such as fishing smacks, &c., and also in rowing boats. In the near future all sailing boats will probably have an auxiliary motor, while no one will ever row a boat except for the purpose of getting exercise.

For stationary work the small cheap prime mover is coming into general use for an enormous number of purposes for which manual labour was formerly in practically universal use. There is also a very great extension of the use of small electromotors in towns as electricity is now universally obtainable.

The extent of the manufacture of these small units is perhaps hardly realised, but certain figures of the total horse-powers produced by some of the American car makers are very illuminating, if compared with the output of a firm making large engines. A marine engineering firm which produces a quarter of a million horse-power a year is a very large firm. Yet Ford produced over 1,000,000 cars last year, and each car was 20 h.p. His total output was therefore over 20,000,000 h.p. Ford, of course, stands all by himself with regard to output, but there are other firms whose output is very considerable. Thus Dodge produced 141,000 cars, and each would be capable of fully 25 h.p. This represents 3,500,000 h.p. The horse-power produced by Buick was probably somewhat greater, while two other firms had an output which must have represented over 2,000,000 h.p. The output of the Detroit district alone for 1920 was 1,848,000 cars, which must represent a horse-power of well over 40,000,000, although last year was not a good one for the American motor trade, and many firms produced far less than they intended.

The outputs of very small marine motors is also very high. Thus one firm which makes small engines of 2 h.p. to 3½ h.p. states that 100,000 have been sold, which represents over 250,000 h.p. even though this firm confines itself to the very smallest units.

In other branches than prime movers the increased use of small machinery is equally evident. The motor car itself consists of many other parts besides the engine, while other kinds of small machinery are coming into use in enormous numbers, and this tendency will very rapidly increase in the future. These range over every conceivable type, from reaping machines to typewriters.

It is very important that the nature of this change in engineering should be thoroughly appreciated and that the design and production of such small machines should be undertaken in a thoroughly scientific spirit. In days gone by when small machines were only made and sold in small quantities it was natural that their design and manufacture should take quite a secondary place compared with larger work. We may take the case of engines as an example. When an order was received for a large engine to develop some thousands of horse-power and costing a proportionate amount of money a very considerable amount of expense was naturally gone to in preparing the design so as to get the best results. Obviously this could not be done in the case of an order for, let us say, a marine engine of 20 h.p. which had to be built for 200*l.* or 300*l.*, and as such engines were only produced in quite small numbers it was impossible to spend a great deal on the design and spread the cost over a great many engines. Naturally, therefore, the producers of large engines could pay the highest salaries to designers, and got the best results. Occasionally extremely able men started business in small work and produced special results, but in this case they usually gradually drifted into the larger classes of work.

This position has now entirely changed, and in order to make the manufacture of the various descriptions of small machinery a success it is necessary that they should be made in quantities, as otherwise it is not possible to produce them at a commercial price. This being so the question of design becomes of far greater importance than when they are made in small numbers, for the simple reason that the total production from one design is so much greater. It is a common error to suppose that small engines and other types of machinery are very much easier to design than large ones; this is not the case. No doubt small machines of inferior design can often be made to go in a sort of way, but to get the best possible results in a small machine requires just as great skill and care as in a large one. Not only must the machine perform its duty as well as it is possible to do so within the limits of size, weight, &c., but it must also be so designed that it is a manufacturing proposition in the shops. This entails a general design which is arranged for cheap erection and, at the same time, for all the detail parts being machined as easy as possible.

In fact, from every point of view the design of small machines is worthy of quite as much scientific study as that of the larger ones now that the production is so great. If, let us say, small engines totalling 50,000 h.p. are to be made from one design, the economy of fuel, freedom from breakdown, simplicity in repairs, &c., is just as important as if the same horse-power was concentrated in two units of 25,000 h.p. each. Cost of production is likely to be even more important in the case of the many small units than the few large ones.

It seems likely that the production of small engines of all kinds and other sorts of small

machinery is likely in the near future to be at least as important commercially as the production of the large engineering units. If we are to be successful in this class of work the matter of design must receive much more attention than it generally has had in this country. It is therefore desirable that really skilled engineers should study the design of small machinery in the same scientific way that they have in previous times studied that of the larger types, and it is of extreme importance that the manufacturing firms should be willing to spend the needful money to get first-rate designs before manufacturing. There is room for a good deal of improvement both in the direction of better results and lower costs in many cases, as can be seen from a careful study of motor designs.

A very small increase in efficiency or reduction of cost aggregates to a considerable amount, if large quantities are made. If a machine selling at, say, 100*l.*, is so improved in efficiency that it will fetch 101*l.* without costing any more to make, and if 10,000 machines are made to that pattern the value of the improvement to the firm is 10,000*l.*, and it would obviously pay very well to spend some thousands of pounds to secure this result. The same applies to an improvement in design reducing the manufacturing cost while giving equal efficiency in the result. This is not the way the matter is always looked at, however, and unless there is considerable improvement in this respect more enterprising countries will absorb the greater part of the small manufacturing trades in the engineering world.

NEW RULES FOR BILLS OF LADING.

THE recent meeting of the International Law Association at The Hague is likely to be well remembered by commercial men owing to the fact that it has produced a set of rules defining the risks to be assumed by sea carriers under a bill of lading. The need for a uniform code which shall be universally observed in all the great maritime countries has been sorely felt for many years. Such a code has now been drafted.

It was unanimously approved by the Maritime Law Committee of the association—a committee which comprised representatives of shipowners, shippers, bankers and underwriters from all parts of the world. The committee having submitted its report, the association passed the following resolution: "That the association approves, under the name of 'The Hague Rules, 1921,' the rules as to carriage by its Maritime Law Committee which have been settled during this conference after consultation with representatives of the interests concerned from numerous maritime States, and recommends the same for international adoption. For the purpose of securing prompt and effective action the association relies upon the continuance of the co-operation among shipowners, shippers, consignors, bankers and underwriters present and represented at the conference which appears to render this proposal at the present time a practical means of progress."

The fact that the committee were able to come to a unanimous conclusion is largely due to the tact and ability of the chairman, Sir Henry Duke, President of the Probate, Divorce and Admiralty Division. His courtesy, his command of simple language easily understood by persons not very well acquainted with English, and his rigorous impartiality—all combined to enable him to perform a task which would have baffled many another man. There were acute differences to be adjusted.

The interests of the various nations represented did not always coincide, while shippers, shipowners, bankers and the underwriters all look at a bill of lading from different points of view.

In the main, of course, the rules as drafted embody the terms which are usually to be found in a bill of lading. But what shipper, say, of machinery, is really familiar with those terms? They are often printed in such small type as to be wellnigh impossible to read; and bills of lading have hitherto assumed no common form. In future it will only be necessary to give a general reference to The Hague Rules, 1921, which he who runs may read. We may draw attention to some portions of the new code, to which, in view of the fact that they gave rise to considerable discussion at the meetings of the committee, great importance appears to attach.

By Article I the term "goods" to which the rules are to apply includes goods, wares, merchandise and articles of every kind whatsoever except live animals and cargo carried on deck, while "carriage of goods" covers the period from the time when the goods are received on the ship's tackle to the time when they are unloaded from the ship's tackle. Article III defines the responsibilities and liabilities of the carrier. It provides (by Clause 1) that the carrier shall be bound before and at the beginning of the voyage to exercise due diligence to (*a*) make the ship seaworthy; (*b*) properly man, equip and supply the ship; (*c*) make the holds, refrigerating and cool chambers, and all other parts of the ship in which goods are carried, fit and safe for their reception, carriage and preservation. Clause 3 of the same article provides that after receiving the goods into his charge the carrier, or the master or agent of the carrier, must on demand of the shipper issue a bill of lading showing amongst other things (*a*) the leading marks necessary for the identification of the goods; (*b*) the number of packages or pieces or the quantity or weight, as the case may be, as furnished in writing by the shipper before the loading starts; and (*c*) the apparent order and condition of the goods. A proviso to the rule absolves the carrier from liability to issue a bill of lading if he has reasonable ground for suspecting that the information given is not accurate.

Very considerable importance attaches to the following clause (4) which has effect to make the shipper or carrier *prima facie* responsible for goods which he may not have actually counted or weighed. It provides that: "Such a bill of lading issued in respect of goods other than goods carried in bulk and whole cargoes of timber shall be *prima facie* evidence of the receipt by the carrier of the goods as therein described in accordance with Clause 3 (*a*), (*b*) and (*c*). Upon any claim against the carrier in the case of goods carried in bulk, or whole cargoes of timber, the claimant shall be bound, notwithstanding the bill of lading, to prove the number, quantity or weight actually delivered to the carrier." By Clause 5 the shipper is to be deemed to have guaranteed to the carrier the accuracy of the particulars supplied by him, and he must indemnify the carrier against loss arising from inaccuracy.

In order to protect the shipper from belated claims in respect of loss, it is provided that unless written notice of a claim is given before removal of goods, such removal shall be *prima facie* evidence of the delivery by the carrier of the goods as described in the bill of lading. In any event an action for loss or damage must be commenced within twelve months of delivery.

To prevent "contracting out" of the conditions it is provided by Article III (8) that any clause, covenant or agreement in a contract of carriage relieving the carrier or the ship from liability for loss or damage to or in connection with goods arising from negligence, fault or failure in the duties and obligations provided in the article for lessening such liability otherwise than as provided in the rules, shall be null, void and of no effect.

To the general liability imposed upon a carrier by Article III, Article IV makes certain exceptions. Thus by Clause 1 he is not to be liable for unseaworthiness of his vessel, unless that is owing to want of due diligence on his part to make the ship seaworthy, or to secure that it is properly manned. Again, by Clause 2 he is not to be liable for damage caused by a number of things over which he has no control, *e.g.*, default of master or pilot, fire, perils of the sea, act of God, act of war or public enemies, strikes, saving life at sea, insufficiency of packing, latent defects, &c. These exceptions to liability have, of course, been inserted in bills of lading for many years past.

Possibly the most important exception of all is that contained in Article IV (4) which is in these terms: "Neither the carrier nor the ship shall be responsible in any event for loss or damage to or in connection with goods in an amount beyond 100*l.* per package or unit or the equivalent of that sum in other currency unless the nature and value of such goods have been declared by the shipper before the goods are shipped and have been inserted in the bill of lading. By agreement between the carrier, master or agent of the carrier and the shipper another maximum amount than mentioned in this paragraph may be fixed, provided that such maximum shall not be less than the figures above named. The declaration by the shipper as to the nature and value of any goods declared shall be *prima facie* evidence, but shall not be binding or conclusive on the carrier."

When this rule was being discussed it was proposed, on behalf of the shipowners, in order to avoid difficulties which might arise in relation to rates of exchange, to limit the shipowner's liability to a sum which should be a multiple of the freight. The French representatives, however, would not agree to this, and the sum of 100*l.* sterling was eventually agreed upon. In effect, therefore, unless a shipper declares that a package or article is worth more than 100*l.* the carrier shall not be liable beyond that amount. The object is merely to secure that the carrier shall be put upon his guard in the stowage of valuable articles. The terms of the clause must not be confused with those of the English Carriers' Act, by which if the consignor of certain goods over 10*l.* in value does not declare their nature and value he is deprived of all remedy for their loss. It is important to notice, too, that according to the clause under notice the shipper must declare the nature of the goods. Considerable objection was raised to this by certain representatives of the shippers on the committee, but on its being pointed out, that the carrier must know the nature of the goods in order to provide for their proper stowage, the objection was withdrawn.

Article IV (6) provides especially for inflammable, explosive or dangerous goods; while Article IV (7) enables a carrier, if so minded, to surrender any part or all of his rights and immunities provided such surrender is embodied in the bill of lading.

Article V provides that a carrier, master or agent of the carrier and a shipper may enter into any agreement in any terms as to his responsibility for any particular goods, and as to his rights and immunities in respect thereof "provided that in this case no bill of lading shall be issued and that the terms agreed shall be embodied in a receipt which shall be a non-negotiable document and shall be marked as such."

At the conclusion of the meeting of the International Law Association, the chairman announced that it was hoped that these rules might become effective in relation to all transactions originating after January 31, 1922. The association also passed a resolution to the effect that whereas special legislation on the subject dealt with by the rules exists in various States and is proposed in other States, and "whereas it will only be possible in such States to bring these rules into operation if they be in accord with national legislation, it is, in the opinion of this association, desirable in order to secure uniformity that such legislation or proposed legislation shall be brought into harmony with these rules."

Whether the Governments of the various countries concerned will take the steps foreshadowed in that resolution is an open question; but there is good reason to hope that the rules will be adopted by commercial men in all countries—a hope which is based upon the representative character of the men who took part in the Hague discussions. In any event, it is conceived that the International Law Association is to be congratulated upon the fact that its labours have borne such good fruit. It was gratifying to find that men interested in the carrying trade of the world have been able to agree upon a code which is destined to promote commercial intercourse amongst the nations.

THE SHIPPING, ENGINEERING AND MACHINERY EXHIBITION AT OLYMPIA.

(*Continued from page* 375.)

MESSRS. TANGENT TOOLS, of Keynsham, Somersetshire, of whom Messrs. Grayson, Rising and Barbour, Ltd., are now the proprietors, show numerous examples of their rotary hand-shears for cutting rods, sheet metal, corrugated iron, &c., and a power-driven machine for dealing with plates up to ½ in. in thickness. These shears are all "throat-

UNIVERSAL TOOL AND CUTTER GRINDER AT OLYMPIA.

CONSTRUCTED BY MESSRS. TANGENT TOOLS, KEYNSHAM, SOMERSETSHIRE.

FIG. 20. UNIVERSAL GRINDING MACHINE.

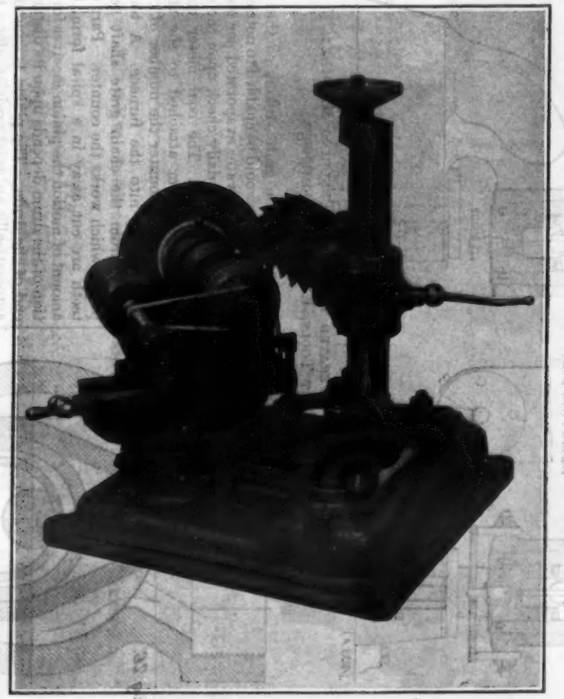


FIG. 21. GRINDING SPIRALLY-TOOTHED MILLING CUTTER.

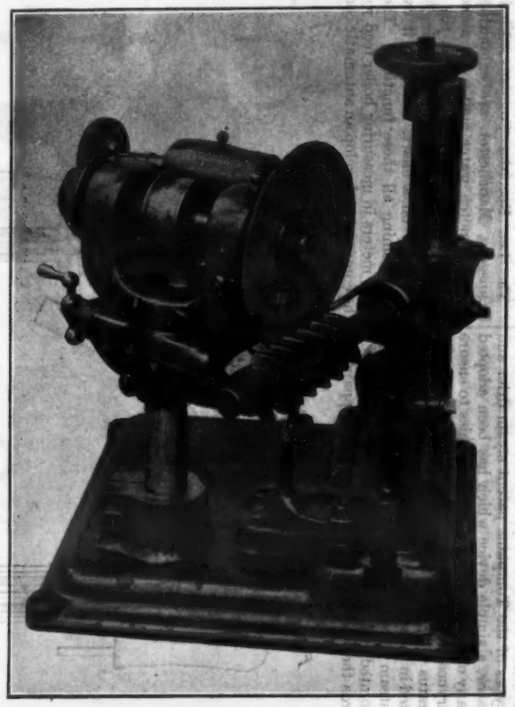


FIG. 22. GRINDING HOBBING CUTTER.

less," and will therefore split plates of any size, and the corrugated-iron shears will cut sheets equally well at any angle to the corrugations. We illustrated the Tangent hand shears in our issue of April 16, 1920, page 524, while the Tangent machine vice for repetition work (which is also to be seen at Olympia) was illustrated on page 441 of our issue of April 2, 1920. The company are now showing a new type of universal tool and cutter grinder, which, like their other products, is of original and attractive design, and of excellent workmanship. This machine is illustrated in Figs. 14 to 22 on page 412 and the present page. The general appearance of the machine, surrounded by examples of the work it is capable of dealing with, is shown in Fig. 20. The cast iron pedestal is of the usual cupboard type containing wooden shelves to accommodate the various tools and accessories belonging to the machine. On the top of the pedestal is a grinding head, carrying a high-speed and a moderate-speed spindle, each running in ball bearings. This head is mounted on a slide, relatively to which it can be locked in any horizontal angular position, so that the grinding wheels can be traversed for cutting either with their faces or their sides. The slide forms the head of a column which permits a considerable vertical adjustment besides enabling the slide to be set so that the traverse is at any angle. In the top of the machine standard are two T slots at right angles to each other, at any point of which the foot of the work-bar may be bolted. This work-bar is of high carbon steel, and is connected to the foot by means of a pair of swivel joints, so that it may be set at any angle whatever both horizontally and vertically. Carried on the work-bar is a sliding head, which can be traversed along the bar, either rapidly by means of a rack and pinion gear or slowly by means of a micrometer feed. The sliding head carries a swivelling vice, clamp, or other fitting suitable for holding the work in hand. It will thus be seen that the machine is thoroughly universal in its movements and settings and capable of practically every imaginable kind of duty within its capacity.

The illustrations, Figs. 14 to 19 on page 412 and Figs. 21 and 22 annexed, show its application to various classes of work, and indicate the universality of its settings. In Fig. 14, page 412, a lathe tool is being ground, the work arm being swung down and locked in a horizontal position, and the work held in a swivelling vice attached to the traversing head of the work-arm. The next illustration, Fig. 15, shows the grinding of a single angle cutter, the arrangements for a spiral angle cutter and for a double angle cutter being shown respectively in Figs. 16 and 18. In the latter illustration the workfingers for rotating the cutter, as the latter is traversed across the wheel, can be seen. They are carried from the wheel-head, but, as will be seen in other illustrations, they can be fixed also to the T slots or to the traversing head. The grinding of a woodruff cutter is shown in Fig. 17, the small high-speed grinding wheel being employed for the purpose. Centre-work on the machine is clearly shown in Fig. 19, the article being ground being a parallel fluted reamer. Fig. 21 shows it arranged for grinding a spirally-toothed milling cutter. Fitted with a different type of grinding wheel, and having its grinding head rotated so that the spindle is at right angles to the work, a hobbing cutter may be ground as in Fig. 22. The machine, which only weighs about 3¼ cwt., is sent out complete with all attachments and with a ball-bearing countershaft.

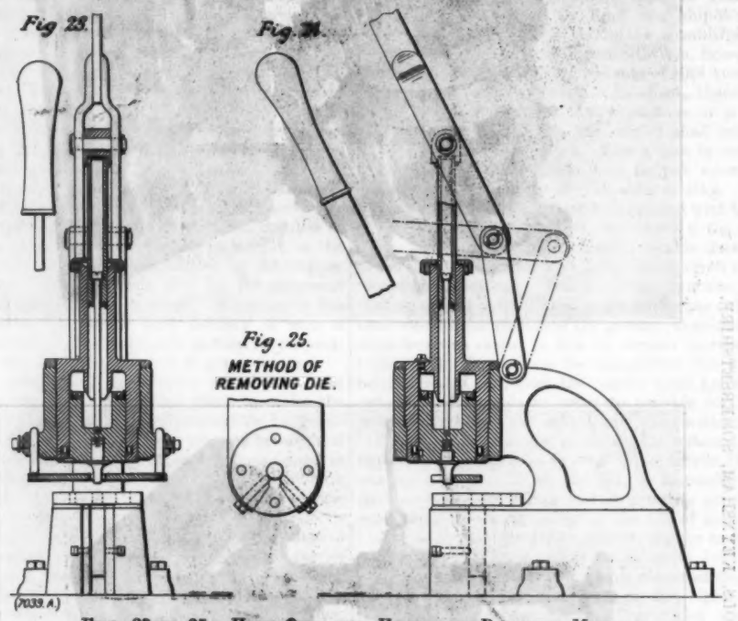
Messrs. Tangent Tools, of Keynsham, also show a new type of hand-punching machine. This punch, which is shown in Figs. 23 to 25 requires only a single pull to punch each hole, so that it is rapid and handy in use. The body of the punch, as will be seen, forms a hydraulic cylinder into which an annular pump ram descends when the lever is pulled. There are no valves of any kind. The pump ram on-nearing the end of its return stroke engages with the head of a pin projecting from the punch ram and withdraws the punch positively from the work. All hydraulic joints are made with cup leathers, and all parts of the machine except the frame are of forged steel. The punch is screwed into the

punch ram, a tommy hole in the latter enabling it to be held when a punch has to be removed or inserted. The die is a circular plate having a central stem projecting below it which serves to locate it. It has holes of various sizes to suit different punches, any desired hole being locked in position by means of the setscrews shown. At one point of the die a snap-hole is sunk, so that when a corresponding snap is inserted in the ram the machine may be used for riveting. The mechanical leverage obtained is 10 : 1, and as the areas of the rams are in the same ratio, the pressure on the punch is 100 times that exerted on the handle. The machine is easily capable of punching holes up to ½ in. diam. through ⅝ in. plate, and ¾ in. diam. through ½ in. plate. It will also close ½ in. rivets cold or ¾ in. rivets hot.

The amount of ingenuity which has been displayed in the invention of valveless rotary pumps is enormous, and there seems no end to the possible ways of designing such articles. Messrs. Pooley and Austin, Limited, of 34, Broadway, Westminster, S.W.1, whose main exhibit consists of small electric motors, dynamos and controlling apparatus show on behalf of Capt. P. H. Sumner of 1B, Shard-square, Peckham Park-road, S.E., a new type of rotary pump, the action of which will be understood from Fig. 26 annexed. The pump body is of the usual cylindrical shape, having an inlet and an outlet branch, and fitted with an end cover forming a bearing for the outboard end of the spindle. The spindle carries a C shaped spring, fixed to it by screws passing through the centre of the spring. Surrounding the spring is a loosely fitting brass sleeve. An endless leather or rubber belt embraces the sleeve and also passes over a bolt between the inlet and outlet branches. When the spindle is revolved, the spring acts as an eccentric and the brass sleeve as an eccentric strap, and the rotation of the spindle causes the belt to move from side to side of the chamber, drawing in water from one branch and expelling it from the other in accordance with the direction of rotation. The elasticity of the spring and also of the leather enable the pump to pass solid particles without trouble. As the belt does not revolve and only presses lightly against the internal surface of the pump chamber, the wear on it is negligible. Several modifications of the "Whipwater" pump as it is called are made, to suit particular conditions or liquids. It is built in sizes from ¾ in. to 4 in. inlet and is light and very moderate in price. On the stand is a ¾ in. pump chaindriven from a small motor, which will deliver 250 gallons per hour against 50 ft. head when running at 900 r.p.m. The total weight of the set complete is only about 50lb.

Messrs. Campbell and Isherwood, Limited, Raleigh-street, Bootle, Lancs., are showing several steam-driven ship lighting sets, the largest being of 55 kw. capacity. The engine, manufactured by Messrs. W. H. Allen, Sons & Co., Limited, is of the totally-enclosed forced lubrication two-crank compound type, having cylinders 9 in. and 14 in. diam. by 6½ in. stroke, and developing 82 b.h.p. at 450 r.p.m. when supplied with steam at 150 lb. per square inch and exhausting against a back pressure of 10 lb. above atmosphere. The connecting rods are three and a half times the length of stroke, a proportion unusually liberal for high-speed engines, but conducive to ease of running, as lower pressures on the crosshead pin and slides are entailed. The generator is of Messrs. Campbell and Isherwood's own manufacture. It is a four pole, interpole, level compounded machine, wound for 100 volts, and designed to carry a 25 per cent. overload for two hours under tropical conditions. A ship's switchboard with three panels for the control of such generators is shown on the stand. The smallest shiplighting set on the stand is illustrated in Fig. 27, page 417. This is of only 3 kw. capacity, and is driven by a Robey open-type engine, having a cylinder 5 in. diam. by 4 in. stroke, and running at 400 r.p.m. A very large number of similar sets up to 15 kw. at 300 r.p.m. have been supplied for shipboard as their simplicity and accessibility are attractive features. Numerous motors of various sizes, watertight and otherwise, are also exhibited, as well as portable electric drilling machines, navigation-light indicators, &c. With the firm's ash-hoist we have dealt on a previous occasion.

Messrs. Ward and Crichton, 41, Chapel Walks, South Castle-street, Liverpool, show various sizes and types of the Tompkins patent steam drier and separator, a simple device which has been adopted by many of the large steamship companies to ensure the dryness of the steam leaving the boilers. The apparatus which is illustrated in Figs. 28 and 29 is inserted in the steam-collecting pipe inside the boiler. The steam flowing along the collecting pipe meets the pointed end of a gunmetal cone, and is deflected towards the walls of the chamber of the apparatus.



FIGS. 23 TO 25. HAND-OPERATED HYDRAULIC PUNCHING MACHINE: MESSRS. TANGENT TOOLS, KEYNSHAM, SOMERSET.

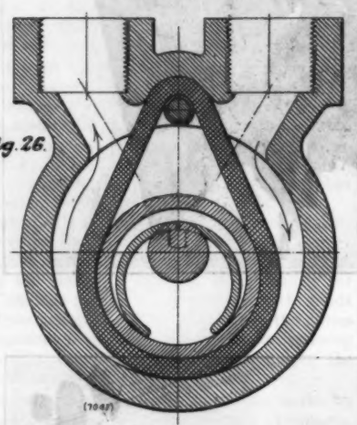


FIG. 26. THE WHIPWATER PUMP: MESSRS. POOLEY AND AUSTIN, LTD., LONDON.

It passes onwards through an annulus containing a number of guide plates which give it a tangential motion, the effect of which is to separate out the particles of moisture by centrifugal force. The water runs back into the boiler through the tangential drain hole shown in the drawings and the steam passes on to the junction valve or to the superheater in a substantially dry condition. A materially higher superheat is naturally obtained when the steam entering the superheater is dry, as otherwise the superheater tubes are partially occupied in evaporating water. Another application of the Tompkins separator is in connection with steam whistles, the design being then as shown in Fig. 30. The object, of course, is to avoid the long pause and the showers of water which commonly occur before a steam whistle sounds when steam has been turned on. The separator is made in either cast iron or gunmetal and the principle of its action needs no explanation in view of the illustration referred to.

The Lea Recorder Company, Limited, of 28, Deansgate, Manchester, are exhibiting their well-known V notch water meters for measuring boiler feed water or condenser discharge, the instruments either indicating the quantity passing, recording it graphically on a chart, totalising it over a period or combining all these functions. The success of these meters in measuring boiler feed water induced the company to develop an automatic coal measuring device for chain grate stokers so that the power-house engineer would be enabled to note continuously the quantity of water evaporated per pound of coal, and so to have a daily check upon the operation of his boiler house. The coal meter consists of a simple mechanism attached to the stoker which registers on a counter the number of cubic feet of coal passing into the furnace. A toothed drum driven from the chain grate shaft gears with a pinion which works the counter. Part of the drum teeth are cut away in a spiral form, so that the amount of motion the pinion receives for one revolution of the drum depends upon its distance from the end of the drum. The pinion is caused to take up automatically an axial position along the drum in accordance with the height of opening of firedoor. The counting gear registers therefore a figure proportional to the speed of the grate and to the thickness of the fire and thus counts the cubic feet of coal burnt. Knowing the weight per cubic feet of the class of coal he is using, the engineer can at once determine the weight burnt over any period of time. Some method of determining the amount of coal used per shift or per day is unquestionably the first step to be taken towards increasing the efficiency of a boiler plant, and the Lea coal meter, being only a fractional part of the cost of any automatic weighing device, should have a wide field of usefulness. It is claimed to be accurate within 2½ per cent., and when one considers the inevitable error of other commercial measuring devices in a power station, such as water-meters, thermometers, pressure gauges, watt-meters, &c., it will be admitted that this is by no means bad. A seven-hour test carried out at a large British power station recently showed an error in measurement of less than 1 per cent., although during the test three different grades of coal were used and the fire varied from 2½ in. to 6 in. thick with different grate speeds.

Messrs. Siebe Gorman and Co., Limited, 187, Westminster Bridge-road, London, S.W., and Messrs. Boulton and Paul, Limited, of Norwich, both show apparatus for raising water by the endless

belt principle. The belt used in Messrs. Siebe, Gorman and Co.'s machines is composed of a number of helical springs wound alternately right and left handed and linked together by pins. The springs are pushed together sideways and held together by the pins which pass through the interlocked coils and thus prevent separation. The springs run the crossway of the belt, their length forming the width of the belt. An endless belt constructed in this way hangs freely from a drum which drives it by frictional contact, the bight at the lower end being steadied by carrying a flanged roller. The lower end is immersed in the water to be raised, and when the belt is run at sufficient speed an extraordinary volume of water is carried up by it and thrown off tangentially into a shoot at the top by centrifugal force. The largest "Aquatole" as the apparatus is called, which is shown on the stand, has a 12 in. belt and will lift 22,000 gallons per hour for an expenditure of power equal to 0·210 b.h.p. per foot of lift. It is said that lifts up to 500 ft. can be provided for without any alteration of design or type. The excessive simplicity of the apparatus and the absence of any kind of valves or piping make it particularly suitable for raising muddy or gritty water. In place of a belt such as we have described, Messrs. Boulton and Paul are using an ordinary canvas belt, on one side of which are riveted strips of metal bent into a zig-zag form. The flexibility of the belt is in no way impaired, as the metal strip undergoes practically no distortion as the belt passes round the pulleys. The zig-zags

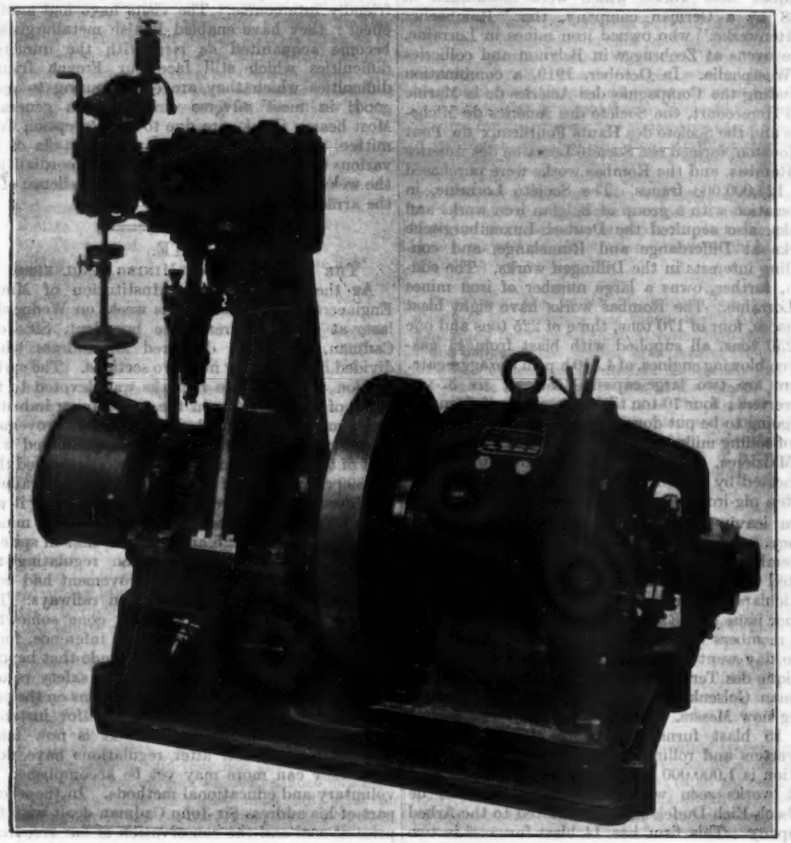
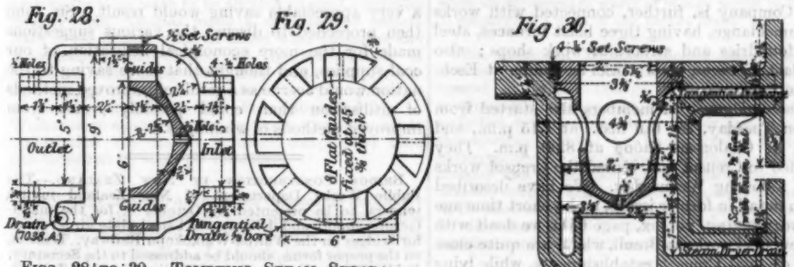


FIG. 27. 3-KW. SHIP-LIGHTING SET: CAMPBELL AND ISHERWOOD, LIVERPOOL.



FIGS. 28 TO 30. TOMPKINS STEAM SEPARATORS: MESSRS. WARD AND CRICHTON, LIVERPOOL.

of the strip form triangular loops covering one side of the belt, and these loops assist in giving a positive lift to the water being raised. Yet a third type of water-lifter depending upon the same principle is shown by Messrs. Boulton and Paul. In this the belt takes the form of an ordinary chain on which are threaded a continuous series of close-wound helical springs. The driving pulley has a circumferential groove, the sides of which grip the springs sufficiently well to prevent slippage. In one example on the stand this type of lifter just described is built in combination with a multi-stage centrifugal pump, the chain raising the water to the eye of the first impeller, and the pump then forcing it to the desired height.

(To be continued.)

OIL FOR POWER PURPOSES.

THE extent to which oil may eventually displace coal for the generation of power has formed the topic for a good deal of misinformed speculation on the part of the daily newspapers. The artificial stimulus given to the use of oil fuel by the recent coal strike, and its increased adoption for marine purposes both for steam raising and for use in internal-combustion engines, have led a certain section of the public to believe that we are on the verge of an "oil era" in which the dirt and labour inherent in coal-firing will to a large extent become things of the past. No one would welcome such a state of affairs more than engineers, but they know only too well that the oil resources of the whole world, so far as can be ascertained, are insignificant as compared with the coal deposits, and that however much headway oil fuel may be apparently making it is practically certain that the use of coal is extending much more rapidly. In Great Britain coal or some of its derivatives must always be the standard fuel for the simple reason that Nature has endowed us with large coalfields of excellent quality and has denied us all but traces of mineral oil. Whatever may be the advantage of oil over coal, its use could never become general in this country, if only for the reason that we could hardly afford to purchase it on a large scale since, on the assumption of enormous foreign oil supplies becoming available, our coal would lose its export value. Nevertheless, at the present time fuel oil is purchaseable at a price which, with its other advantages, makes its use a commercial proposition, particularly for marine purposes, and the interest in the question has led to the holding of an oil conference in connection with the Shipping, Engineering and Machinery Exhibition now being held at Olympia.

The first session of the conference opened on Wednesday last with a paper on "The Application of Oil for Power Purposes," by Mr. Sidney H. North, Assoc.M.Inst.P.T. After calling attention to the admitted advantages of oil over coal, the author gave figures to show the increase of efficiency which had been attained in the consumption of oil whether for steam raising or for direct use in internal-combustion engines, since first it was employed for these purposes. No one doubts the contention that oil, when available at a reasonable price, is an almost ideal fuel, particularly at sea, where questions of bunkering, ash-disposal and the diminution of the number of stokehold "passengers" are of such importance. On land, labour-saving in coal and ash-handling, and the controllability of the fires, are the main advantages, and although these would seem great enough to give oil fuel a firm foothold when once it was installed, it is significant to note that one of the largest London power stations, which adopted oil firing on an extensive scale during the coal strike, is reported to have reverted almost entirely to the use of coal. A similar reversion to coal is reported in the case of railways which used oil in their locomotive furnaces during the strike, but as no labour-saving could be effected by burning oil on locomotives, the return to coal is less to be wondered at.

The real reason why power station engineers and large manufacturers hesitate to commit themselves to a wholesale adoption of oil fuel was clearly put by a speaker in the subsequent discussion, who pointed out the monopolistic nature of the supply. Very many large power users would use oil if they were sure of being able always to get it at a reasonable price. There are scores of firms in the country who will sell oil by the ton or by shiploads, but they are all dependent for their supplies upon one or two huge corporations who hold a virtual monopoly of the oil resources of the world. Anyone who equips a power station with pumps and tanks and oil-burning furnaces instead of elevators, coal bunkers and mechanical stokers, at once delivers himself into the hands of a few men in a foreign country who can double the price of his

fuel or withhold it altogether at any time they think fit to do so. Were the sources of oil more widely distributed and owned by a very large number of independent companies, as the coal mines are, so that free competition existed and economic laws alone determined the price, then people would consider the use of oil entirely on its commercial merits. The user of an internal-combustion engine is even more helpless against the manœuvres of the oil corporations than the owner of an oil-fired boiler plant, for he has no possible alternative fuel to fall back on, whereas coal-firing can always replace oil-firing should the expense of the conversion of the furnaces be warranted.

The second paper at the conference was on the "Nomenclature and Specification of Oils for Power Purposes and their Uses," the author being Mr. J. Venn-Stevens. This dealt principally with the chemical composition and the physical characteristics of the various distillates from crude petroleum, ranging from petrol to the heavy fuel oils. The advisability of having internationally accepted standard names and specifications for the various kinds of oil was emphasised, and it was mentioned that the Institution of Petroleum Technologists are now considering this question. The conference will be resumed on Wednesday, September 21, at 3 p.m.

THE IRON AND STEEL INSTITUTE.

As stated in the account in our issue of last week (page 382 *ante*), of the meetings of the Iron and Steel Institute in Paris for the reading and discussion of papers, the members subsequently formed into three groups to visit iron and steel works and engineering establishments in France.

Members to the number of about 100 started from Paris on Tuesday, the 6th inst., at 4 p.m., for Lorraine, the headquarters being Metz, where they arrived at 10.40 p.m. The first visit, on the morning of Wednesday, the 7th inst., was to the Hayange Works of Messrs. de Wendel and Co. These establishments have been the property of the de Wendel family since 1704; they consist of four blast furnaces at Hayange (two of 200 tons and two of 150 tons, which latter are to be replaced by two of 200 tons); and six blast furnaces at Paturel (two of 180 tons and four of 225 tons). The steel works contain six basic converters. There are, further, cogging mills, and rail, girder and sleeper mills. The open-hearth plant consists of four 60-ton furnaces, a fifth being in course of construction. Combined with this are plate and sheet mills, and a galvanising plant. The Moyeuvre Works belonging to the same firm, and no great distance away, have eight blast furnaces, four basic converters, and bar and rod mills. In 1913, the production was 847,000 tons of pig-iron and 773,000 tons of steel.

The members then proceeded to the Jœuf and Messempré Works, also owned by the same firm. In connection with these, it may be stated that after the war of 1870, when Germany took Alsace-Lorraine, the Hayange and Moyeuvre Works above referred to were outside the French frontier, and Messrs. de Wendel, in association with Messrs. Schneider, decided to put down works at Jœuf, in France. The Jœuf works were started in 1880, and produced in 1913, the last complete year before the late war, 394,000 tons of pig-iron and 330,000 tons of steel. We dealt with the destruction and restoration of these works in a former issue (see ENGINEERING, vol. cxi, page 672). Their reconstruction is being pushed forward actively.

The next places of call were the Homécourt Works, belonging to the Compagnie des Forges and Aciéries de la Marine et d'Homécourt (St. Chamond Company), to which we also referred in the issue of ENGINEERING above referred to.

The iron mines of Droitaumont, which were viewed on Wednesday, belong to the Société des Mines de Droitaumont (Schneider and Co.). The ore contains from 34 per cent. to 40 per cent. of iron, the shafts average about 600 ft. in depth, and the output during 1913 was 404,687 tons.

On Thursday, the 8th inst., the members proceeded to the Hagondange Works, which were put down by Thyssen between 1911 and 1914; they were acquired after the late war by a group of French works. They contain six 300-ton blast furnaces, five 30-ton converters, one 80-ton tilting open-hearth furnace, one 60-ton open-hearth furnace, two 10-ton and one 18-ton electric furnaces. These works have a capacity of production of 600,000 tons per annum. The new company owns about 14,000 acres of iron ore concessions in Lorraine.

The works next visited on Thursday were the Rombas steel works, which were established in 1888 by a German company, the "Rombacher Hüttenwerke," who owned iron mines in Lorraine, coke ovens at Zeebrugge in Belgium and collieries in Westphalia. In October, 1919, a combination including the Compagnie des Aciéries de la Marine et d'Homécourt, the Société des Aciéries de Micheville and the Société des Hauts Fourneaux de Pont à Mousson, formed the Société Lorraine des Aciéries de Rombas, and the Rombas works were purchased for 125,000,000 francs. The Société Lorraine, in association with a group of Belgian iron works and banks, also acquired the Deutsch-Luxemburgische works at Differdange and Rumelange, and controlling interests in the Dillingen works. The concern, further, owns a large number of iron mines in Lorraine. The Rombas works have eight blast furnaces, four of 170 tons, three of 225 tons and one of 250 tons, all supplied with blast from 11 gas-driven blowing engines, of 4,810 h.p. in the aggregate. There are two large-capacity mixers, six 32-ton converters; four 70-ton tilting open-hearth furnaces are going to be put down. There is also a powerful set of rolling mills. Four 200-ton blast furnaces are at Maiziéres, with which the Rombas works are connected by a 5-mile railway track, which enables molten pig-iron to be brought to the mixers.

On leaving Rombas, the main party went to Nancy, and about 20 members proceeded to Luxemburg. The former, on Friday, the 9th inst., visited the works of the Société de Pont à Mousson, particulars concerning which will be found in a former issue (see ENGINEERING, vol. cxi, page 672). The members who proceeded to Luxemburg on the same day went to the works of the Société Métallurgique des Terres Rouges, formerly owned by the German Gelsenkirchen Company, the main owners being now Messrs. Schneider and Co. The Société has 15 blast furnaces in three localities, basic converters and rolling mills; the capacity of production is 1,000,000 tons of steel per annum. The next works seen were the Aciéries Réunies de Burbach-Eich-Dudelange, abbreviated to the Arbed Company. This firm has 14 blast furnaces in two different localities, combined in both cases with basic converter and open-hearth furnace plants, also a number of rolling mills and foundries. The Arbed Company is, further, connected with works at Dommeldange, having three blast furnaces, steel plant, foundries and structural work shops; also with blast furnaces, steel works and mills at Esch-sur-Alzette.

The second group of members also started from Paris on Tuesday, the 6th inst., at 1.15 p.m., and arrived at Chalon-sur-Saône at 8.50 p.m. They proceeded to Creusot and visited the Creusot works on the following Wednesday. We have described these in detail in former issues, and a short time ago (see ENGINEERING, vol. cx, page 631), we dealt with their new steel works at Breuil, which are quite close to the original Creusot establishments, while lying between the two are extensive locomotive shops having a capacity of 300 locomotives per annum. At a short distance from Creusot, at Montchanin, is a new establishment put down by the firm and called the Henri-Paul Works, named after Mr. Schneider's eldest son, a French Army officer who was killed during the war in an aeroplane engagement. These latter works comprise an iron and a brass foundry, with pattern shops, and 80 coke-ovens with by-product recovery.

From Creusot, the members proceeded to St. Chamond, *via* Lyons, and visited the St. Chamond works (Compagnie des Forges et Aciéries de la Marine et d'Homécourt) on Thursday, the 8th inst.

The third group of members started from Paris on Wednesday morning, the 7th inst., and on the same day visited the Mondeville-Colombelles works of the Société Normande de Métallurgie, which we described in former issues (see ENGINEERING, vol. cvii, page 136, and vol. cix, pages 180 and 293). On the following day they visited the Soumont iron mines belonging to the company.

The visitors were everywhere received, both in Paris and in the provinces, with the greatest cordiality. We feel confident they will bring back with them a most pleasing recollection of their stay with the numerous French colleagues they have been able to meet, with whom, we are confident also, they will remain in the future in most friendly intercourse. The visits have had another effect; they have enabled British metallurgists to become acquainted *de visu* with the numerous difficulties which still face our French friends, difficulties which they are endeavouring to make good, in most adverse circumstances generally. Most hearty thanks are due to the Reception Committee, and to the owners and the staffs of the various establishments visited, for the cordiality of the welcome accorded, and for the excellence of all the arrangements made.

NOTE.

THE INSTITUTION OF MINING ENGINEERS.

AT the meeting of the Institution of Mining Engineers, which opened this week, on Wednesday last, at Stoke-on-Trent, the president, Sir John Cadman, K.C.M.G., delivered an address which divided itself roughly into two sections. The earlier portion of Sir John's remarks was devoted to the effect of legislation upon the coal-mining industry, and figures were quoted showing the improvement in safety of the working miner as compared with that of the railway employee. Records showed that in 1899 the number of fatal accidents among railway employees was 1·31 per 1,000, while last year it was 0·71. The corresponding figures for coal miners were respectively 1·26 and 0·88, so that in spite of the greater degree of legislation regulating the working of coal mines, the improvement had been smaller than on the less-regulated railways. The president might, we think, have gone somewhat further than he actually did in his inference, for it would not have been amiss to conclude that beyond a certain point less improvement in safety results from regulations than from co-operations on the part of employees in such directions as, for instance, the "safety first" movement. It is now fairly well established that after regulations have done what they can more may yet be accomplished by voluntary and educational methods. In the second part of his address Sir John Cadman dealt with the price of coal and the conservation of our resources, pointing out that if the collieries themselves used the coal they consume, amounting to about 8 per cent. of their output, on the best modern methods a very appreciable saving would result. Sir John then proceeded to discuss the various suggestions made for the more economical utilisation of our coal supplies, and thought that more saving to the nation would accrue as a result of improved methods of utilisation than could possibly result from improved methods of winning it.

BRIDGE CONSTRUCTION IN NEW ZEALAND.—The Public Works Department of New Zealand invites tenders, to be presented by October 4, for the manufacture, supply and delivery of 11 steel-plate girder spans for bridges on the Wairoa-Waikokopu Railway. Tenders, on the proper forms, should be addressed to the Secretary, Public Works Tenders Board, Wellington, New Zealand. In view of the limited time it will be necessary for United Kingdom firms wishing to submit tenders to cable their agents in New Zealand. A set of the relative documents, including blue prints, may be seen by United Kingdom firms interested on application at the Department of Overseas Trade (Room 50A), 35, Old Queen-street, Westminster, S.W. 1.

PERSONAL.—Mr. John E. Dorman, late director of W. H. Dorman and Co., Limited, of Stafford, and for the last twenty years intimately concerned with the management of the firm, has severed his connection with them and has joined the Board of Messrs. Henry Meadows, Limited, Fallings Park, Wolverhampton, makers of the well-known Meadows' four-speed gear boxes and other automobile components.—Bucyrus Company, excavating and mining machinery makers, headquarters at South Milwaukee, Wisconsin, U.S.A., and formerly represented in the British Isles by Messrs. G. F. West and Co., wish to announce that they have now opened their own office at 19, Iddesleigh House, Caxton-street, Westminster.—Mr. Frank H. Brunt, M.Inst.C.E., has removed from 100, to 120, Victoria-street, Westminster (telephone number Victoria 8477).

OFFICIAL TRIALS OF GERMAN ARMOUR PLATES.

TRIALS have recently been undertaken to test the quality of various types of German armour plates for the purpose of comparing them with plates of corresponding thickness manufactured in this country. The plates were obtained from the ex-German battleship Baden, and are therefore thoroughly representative of the German product.

The following table setting forth the results of these trials indicates the marked superiority of British armour plates. In the table the average limiting velocity of penetration for British plates is taken to be 1,000 ft. per second in each case, and the third column shows the comparative figures for German plates. The shells used at these trials were of similar mark and quality to those used in testing British plates of the same thickness.

Thickness of Plate in Lb. per Sq. In.	Index Number Representing Limiting Velocity of Penetration. British.	German.
80 Bulkhead plate....	1,000	1,000
160 Turret roof plate....	1,000	Less than 955*
200 Turret roof plate....	1,000	Less than 935*
320 K.C. armour	1,000	940
400 K.C. armour	1,000	Less than 895*
480 K.C. armour	1,000	Less than 835*
560 K.C. armour	1,000	915

* In these cases owing to the limited space available for attack, the velocities could not be taken low enough to determine the limiting velocity, the shells, at the velocities indicated by the index figures, passing on practically undamaged, except in the case of the 200-lb. roof plate.

INDUSTRIAL NOTES.

THE Trades Union Congress, held this year at Cardiff, and to which we referred in this column last week, was still in session at the time of going to press. Thursday, the 8th inst., was a mixed day made up of debates on disarmament, minimum wages and the so-called efforts of employers to lower the standard of the worker's life. A discussion of the principle of disarmament is rather outside our field, but its bearing on industry is interesting. While avoiding everything which might possibly be regarded as bias, it is allowable to point out the curious position in which a resolution such as that passed by the Congress on Thursday places many labour leaders. Mr. Thomas, in support of limiting armaments, said they had got to say to their dockyard and other workers whose livelihood depended on armaments, that they also must not press for battleships merely because they found a living by them. Most of us, however, will remember numerous instances, when one Government or another has reduced work at the dockyards, Woolwich or elsewhere, of deputations mainly composed of labour representatives craving for more work to be allotted to some particular locality. Mr. Thomas made a very shrewd remark later in the debate when he asked what engineers and boilermakers who existed by the manufacture of munitions were doing when they continued to make such things and then expected the railwaymen to refuse to carry them. Mr. Ben Tillett and Mr. J. Walker were among the few speakers who appeared to realise that the matter is more complicated than can be solved by a simple resolution.

On Friday last one of the most interesting and lively debates of the Congress occurred. The day was devoted to the relief of distress in Russia, trades union education, the question of a whole time chairman for the General Council, the housing question, and, lastly, but perhaps most interesting of all, a general resolution on strikes. This resolution called for the provision of adequate machinery for the settlement of industrial disputes, without recourse to strikes, and failing such settlement a co-ordination of resources so as to ensure a successful issue. The idea of the promoters appeared to be that isolated strikes should not occur, and that only after approval of the General Council should a stoppage be brought about. Mr. A. Pugh, of the Iron and Steel Workers, in moving the resolution, made the interesting statement that not more than 1 per cent. of strikes were justified by results. Mr. A. Hayday, of the General Workers' Union, said they had had to spend 400,000*l.* in unemployment benefit as the result of the miners' strike, and expressed the strongest disapproval of one union striking without regard to and without consultation with others who might be thrown out of employment by the action. There were naturally many speakers in opposition, including Mr. J. Hill, of the Boilermakers' Society, Mr. C. T. Cramp, of the National Union of Railwaymen, whose love of the threat of a lightning strike is well known, representatives of the miners and others. The resolution was lost by a majority of over 4,500,000, but it is significant that close upon a million votes were cast in favour of it—an indication that there is an important body of labour which is tiring of the disastrously unsettled state in which the industrial world has been kept in recent years.

Earlier in the day the education of trades unions was discussed, and a resolution passed instructing the General Council to consider the best means for promoting this, and the effective working of trades union colleges. The resolution was moved by Mr. C. G. Ammon, of the Postal Workers' Union, and was supported by Mr. Frank Hodges, who spoke of the dangers of an uneducated democracy in power, and the short life which it would have. He said he was not pleading for the education of young men as missionaries or propagandists, but for their training as possible administrators, all of which may be taken as indicative of a realisation that mere denunciation, on which so many labour spokesmen rely, will not carry the world very far, and that if labour is to come into power, the hope for its success lies in producing something more in the way of administrative ability than has been evident in the past.

Practically the whole of Saturday's—the last—sitting of the Congress was taken up by a discussion concerning the General Council vote. After the result of the ballot for the election of a General Council, and for the American and Canadian delegations had been announced, Mr. Frank Hodges, of the Miners' Federation, asked how it occurred that Mr. Herbert Smith, of the same federation, was credited with only 818,000 votes, whilst the full vote of the Federation was 900,000. Mr. A. Gee, the chairman of scrutineers, replied that when a society had voted for more candidates than there were in a particular group, the votes should be disallowed. There was one paper with 900,000 on top, and votes had been given for five or six different candidates, when only two were required. Mr. J. H. Thomas said the scrutineers had exceeded their duty; then followed the discussion referred to, and the Congress decided on a new ballot by 2,780,000 votes to 1,823,000. The Parliamentary Committee is to continue to carry on the work of the Congress until the result of the new ballot is known. The president then stated that Belfast was on the agenda for the Congress next year; in view, however, of the situation in Ireland, he suggested that the question be left in the hands of the General Council. This was agreed to.

We note that in the Chicago building trades dispute an award has been made by the referee by which wages will be reduced from 10 per cent. to 30 per cent., and many restrictions abolished. The award includes the principle of the "open shop," if sufficient union men are not forthcoming for the work, as well as the abolition of all restriction on daily output. Another invaluable clause permits small jobs which would occupy less than half an hour being done by a man of another trade when an unnecessary waste of money would be involved in employing a man of the proper trade.

The Industrial Welfare Society has organised a lecture conference for welfare supervisors which opened at Balliol College, Oxford, yesterday, and continues till Tuesday next, the 20th inst. Yesterday's activities were confined to a dinner and, afterwards, the opening address by Lord Gorell. To-day and subsequently the programmes are lengthy, there being morning and evening lectures and discussions. We note that the subjects are not merely confined to economics, while since all meals appear on the programme it may be taken that the conference is to some extent a social function combined with instruction.

The Ministry of Health's instructions to Boards of Guardians as to how to deal with the unemployment crisis may be summarised in a few words. The relief granted should be on a somewhat lower scale than the earnings of a man maintaining himself by his labour. No relief should be granted without full investigation into the circumstances, and no relief in money granted until the case has been reported upon. Relief in kind should be given when practicable, while it may also be granted by way of loan.

In the issue of *The Times* for last Wednesday, an article on Unemployment and Finance gave the following figures: "German prices of raw materials are about 44 per cent. below British, whilst German wages are about one-third to one-quarter of British wages. Not only is the German workman's standard of living about one-half of what it was before the war, and also distinctly below that of the British workman, but as a productive agent he is highly efficient. Moreover, thanks to German trade activity, he is able to work overtime and offset his low unit of wage by earning more units. . . . There can be no permanence in the German price advantage, for so long as Germany pursues a policy of inflation her prices will continue to rise and her wages bill will follow. This is now taking place. German prices are rising rapidly, owing partly to the abolition of the bread subsidy. Meanwhile, we have no alternative but to endeavour to force down our prices until a parity is established with those in Germany."

The Association of British Chambers of Commerce has written to the Minister of Labour asking that a lead be given in the matter of scales of wages on public relief works, the view being that this scale should be based on reasonable remuneration and not the trades union rate of wages. The object should be to make the relief funds go as far as possible, by not offering any inducement for men at work to leave their jobs for better pay on unemployment relief undertakings.

Difficulties which have existed for some time in the printing trades with reference to wages reductions have been eased by the following statements, which may, it is hoped, be the prelude to a settlement:—

An agreed statement has been made to the Press by Mr. A. E. Goodwin, Secretary of the Federation of Master Printers, and Mr. A. E. Holmes, Secretary of the Printing and Kindred Trades Federation. It reads:—

"At a conference held in London on Tuesday, the 13th inst., it was agreed that the employers would suspend their notices so as to enable the unions to take a ballot of their members, to be returnable by September 27, on the question that the first five shillings of the proposed reduction shall take effect on the pay day in the week ending October 1. In the event of the unions recommending the acceptance of the employers' terms the second reduction, amounting to 2s. 6d., shall take effect on the pay day in the week ending January 7, 1922."

A second agreed statement issued to the Press by Mr. A. E. Goodwin, Secretary of the Federation of Master Printers, and Mr. H. Skinner, of the Typographical Association, reads:—

"A conference was held on the same day between the Federation of Master Printers and the Executive of the Typographical Association, when it was agreed that notices posted in the printing trade in the provinces affecting Typographical Association members, and expiring on the pay day in the week ending September 17, 1921, should be suspended until the pay day in the week ending October 1, 1921, and that the Typographical Association Executive should in the meanwhile take a ballot of its members with a recommendation for acceptance on the following proposal: Reduction in wages of 5s. per week on the pay day in the week ending October 1, 1921, and a further reduction of 2s. 6d. on the pay day in the week ending January 7, 1922."

TRADE UNIONIST AND CAPITALISM: ERRATUM.—On page 379 of our last issue, column 3, line 20 from top, "100,000,000*l.* per annum" was, by a slip of the pen, written for 100,000,000*l.* simply as had been intended. The slip unfortunately escaped detection in proof.

THE NORTH SHORE BRIDGE, SYDNEY.—The Agent-General for New South Wales has received intimation from his Government that it is proposed to invite tenders for the erection of the North Shore Bridge spanning Sydney Harbour. The bridge will carry a railway and tramway, as well as ordinary vehicular and pedestrian traffic, and will, it has been estimated, take ten years to complete. The specifications are expected to reach London about the end of November. It is understood that the closing date for tenders will be September, 1922.

FINSBURY TECHNICAL COLLEGE OLD STUDENTS' ASSOCIATION.—The annual general meeting of the above association was held at Finsbury Technical College on September 5, and the president, Dr. G. T. Morgan, O.B.E., D.Sc., F.R.S., took the chair. A report was read of the progress made since the association was resuscitated in the early part of 1920, and although space does not permit mention of all its activities, we must refer to the great success of the dinner and smoking concert held last season. The fact that Finsbury is being kept open, and, as a result, in no small measure to the individual and collective efforts of old students of the college, should impress on all the necessity of maintaining this association, and should ensure a steady influx of new members. Students who have recently completed their course would be well advised to apply for membership if they have not already done so. The annual dinner this year has been arranged for November 12, and the smoking concert for January 27, both these functions being held at the newly-opened Engineers' Club. The first number of a bulletin which it is proposed to issue quarterly is in the course of preparation, and all old students are requested to forward immediately an account of what they are now doing for inclusion in same. Application forms for membership and all particulars of the association may be obtained from the Hon. Secretary, H. P. Guy, 209, Northumberland Park, Tottenham, N. 17.

NOTES ON WATER-POWER DEVELOPMENT.*

Address by Professor A. H. GIBSON, D.Sc., President of Section G of the British Association.

THE extent to which the water powers of the world have been investigated and developed during the past decade forms one of the striking engineering features of the period. Although falling or flowing water formed the earliest of the natural sources of energy to be utilised for industrial purposes, it is of interest to note that two-thirds of the water power at present in use has been developed within the last ten years. The reasons for the revival of interest in this question are partly technical and partly economic.

The technical development of electric generation and transmission has made it economically possible to utilise powers remote from any industrial centre, while a rapid increase in the demand for energy for general industrial purposes and for the many electro-chemical, electro-physical, and electro-metallurgical processes which are now in general use, and whose field is rapidly growing, has provided a ready outlet for all such energy as could be cheaply developed.

The urgent demand for energy to supply the abnormal requirements of the war period, combined with the world shortage of fuel, was responsible for an unprecedented rate of development in most countries with available water power resources, and especially in those countries normally dependent on imported fuel.

Thus in France some 850,000 water horse-power have been put into commission since 1915, and the country now has 1,600,000 h.p. under control as compared with 750,000 before the war. In Switzerland some 600,000 h.p. have been developed since 1914, or are in course of construction, as compared with 880,000 h.p. before the war. In Spain, where the pre-war output was 150,000 h.p., the present output is 620,000 h.p., and about 260,000 h.p. are now in course of development, while the Spanish Ministerio de Fomento is considering the development of some 2,000,000 h.p. to be delivered into a network of transmission lines covering the industrial parts of the country.

In Italy, schemes totalling about 300,000 h.p. are under way, and it is estimated that the total output will shortly amount to 2,000,000 h.p. The Government Hydrographical Department is now engaged in gauging and surveying the profiles of the principal rivers, and statistics of available reservoir sites, of lakes suitable for storage and of avilable horse-power, are being compiled.

Japan, which only very recently began to investigate her water powers, has, since 1916, developed over 1,000,000 h.p., or almost 20 per cent. of her available resources.

In Canada and the United States many large schemes have recently been brought into service, and some extremely large installations are now in course of construction or are projected. Thus the Queenston-Chippawa project on the Canadian side of the Niagara River is intended to develop some 500,000 h.p., while a projected development of the St. Lawrence River will be capable of yielding 1,700,000 h.p. In Canada the total development (2·3 million h.p.) in 1918 was almost three times as great as in 1910. In the United States of America the development has increased from something under two million horse-power in 1901, to 5·3 millions in 1908, and to nearly 10·0 millions in 1920.

Rapid as has been the development of water power in the United States in the past, it has been retarded by the fact that the privilege of using the national forests or other public lands for water power development has only been granted by the issuing of permits which were not available for any definite period and which were revocable at the will of the granting authority. In the case of development on navigable streams, whether on public or private land, each scheme has required a special Act of Congress, and these Acts could be revoked by Congress at any time. Owing to the uncertainty of tenure there has naturally been some reluctance to invest capital in such undertakings.

By the recent Federal Water Power Act, signed in June, 1920, licences for such developments may now be issued under the jurisdiction of a new body, known as the Federal Power Commission, for a period not exceeding 50 years, at the end of which the licence may be renewed, or the Government may take over the enterprise upon compensation of the licencees. In the issuing of licences, preference is to be given to State and municipal applications. The effect of this Act may be inferred from the fact that, within a month of its being signed, applications for licences to develop over 500,000 h.p. had been filed. The duty of collecting, recording, and publishing data regarding the utilisation of water resources, the water-power industry and its relation to other industries, and regarding the capacity, development costs, and relationship to possible markets, of power sites, has also been assigned to this Federal Power Commission.

World's Available Water Power.—During the past few years much attention has been paid to statistics of available and developed water powers. In the case of developed powers, these are usually stated in terms of the capacity of the installed machinery. This machinery is in general only used to its full capacity over a portion of each day, although in many such cases water is available for providing continuous power if desired.

Estimates of potential power are always to be accepted with considerable reserve. In order to make a reasonably accurate estimate, the run off from the catchment area and the variation in this run off from month to month and from year to year, must be known, and it is only in comparatively rare cases that this information is as yet available. Moreover, there is as yet no standard basis on which potential power is computed.

The power available from a given stream during the wet season is many times as great as during the dry season unless sufficient storage is available to equalise the flow throughout the year, and the cost of such storage would in general be prohibitive, even if it were physically possible to provide it.

The United States Geological Survey takes the maximum useful flow of a stream as being that which may be guaranteed during six months in each year. The minimum flow is taken as the average which can be guaranteed over the two driest consecutive seven-day periods in each year, along with the additional flow which may be obtained during this period by developing any available storage capacity in the upper waters of the stream. Estimates of potential power based on storage capacity are, however, subject to a wide margin of error owing to the limited data available, and in the following table the potential water power is estimated on the basis of the maximum flow as just defined, and in terms of continuous 24-hour power.

(*Millions of Horse-Power.*)

—	Available.	Developed.
Great Britain	0·9	0·2
Canada	23·0	3·28*
Remainder of British Empire including—		
Australia		
Africa (East)		
" (South)		
" (West)	30·0 to 50·0	0·7
British Guiana		
India and Ceylon		
New Zealand		
Papua		
Austria	5·5	0·57
Brazil	26·0	0·32
Dutch East Indies	5·5	—
France	5·8	1·6
Germany	1·5	0·75
Iceland	4·0	1·0†
Italy	4·0	1·25
Japan	8·0	1·5
Norway	7·5	1·25
Russia	20·0	1·0
Spain	5·0	0·88
Sweden	6·2	1·2
Switzerland	4·0	1·4
United States of America	28·0	9·8

* Including projected extensions to plants now in operation.
† Projected but not yet constructed.

Adopting these figures it appears that the available horse-power of the world is of the order of 200,000,000, of which, approximately, 25,000,000 is at present developed, or is in course of development.

Power Available in Great Britain and in the British Empire.—With the noteworthy exceptions of Canada and New Zealand, practically nothing had been done, prior to 1915, by any part of the British Empire, to develop or even systematically to investigate the possibilities of developing its water powers. It is true that a number of installations of some considerable size had been constructed in India and Tasmania, but their aggregate output was relatively inconsiderable.

Since then, however, there has been a general tendency to initiate such investigations, and at the present time these are being carried out with varying degrees of thoroughness in India, Ceylon, Australia, South and East Africa, and British Guiana. While it is known that there is ample water power in Newfoundland, Nigeria, Rhodesia, Papua, and the Gold Coast, no very definite information is available, nor are any steps apparently being taken to obtain data in these countries.

The Water-power Committee of the Conjoint Board of Scientific Societies, which has been studying the state of investigation and development throughout the Empire since 1917, has, however, come to the conclusion that the total available water power resources are at least equivalent to between 50,000,000 h.p. and 70,000,000 h.p.

Of the developed power in the Empire about 80 per cent. is in Canada. Throughout the remainder of its territories only about 700,000 h.p. are as yet developed, or only a little over 1 per cent. of the power available, a figure which compares with about 24 per cent. for the whole of Europe, and 21 per cent. for North America, including Canada and the United States of America. These figures sufficiently indicate the relatively large scope for future development.

Power Available in Great Britain.—With a view to ascertaining the resources of our own islands, a Board of Trade Water Power Resources Committee was appointed in 1918. This Committee, which has just presented its final Report, has carried out preliminary surveys of as many of the more promising sites as its limited funds allowed, and has obtained data, from the Board of Agriculture for Scotland, the Ordnance Survey Department, the Ministry of Munitions, and from civil engineers in private practice, regarding a large number of other sites.

As might be anticipated, Scotland, with its comparatively high rainfall, mountainous area, and natural lochs, possesses relatively greater possibilities than the remainder of the United Kingdom, and investigation has shown that it offers a number of comparatively large schemes. Nine of the more immediately promising of those examined by the Committee have an average output ranging from 7,000 to 40,000 continuous 24-hour horse-power, and an aggregate capacity of 183,000 h.p., while in every case the estimated cost of construction is such that power could be developed at a cost appreciably less than from a coal-fired station built and operated under present-day conditions. The aggregate output of the Scottish schemes brought before the notice of the Committee—some of which, however, are not commercially feasible at the moment—is roughly 270,000 continuous horse-power.

In addition to these there are a very large number of other small schemes which have not yet been investigated, and it is probably well within the mark to say that there are water-power sites in the country capable of developing the equivalent of 400,000 continuous horse-power, or 1,500,000 h.p., over a normal working week, at least as cheaply as from a coal-fired installation.

A number of attractive schemes are also available in North Wales, though these are in general more expensive than those in Scotland.

Owing to the general flatness of the gradients, there are, except possibly around Dartmoor, no schemes of any large individual magnitude in England, but there are a large number of powers ranging from 100 h.p. to 1,000 h.p. which might be developed from river flow uncontrolled by storage.

Investigations on a few typical watersheds throughout England and Wales appear to show that the possible output averages approximately eight continuous horse-power per square mile of catchment area, which would be equivalent to an aggregate of about 450,000 h.p. Although much of this potential output is not commercially feasible, it would give the equivalent of 500,000 h.p. over a normal working week if only 30 per cent. of it were fully utilised.

In the report recently issued by the Irish Sub-Committee of the Board of Trade Water Power Committee, it is estimated that approximately 500,000 continuous 24-hour horse-power are commercially available in Ireland, and that if utilised over a 48-hour working week, the country's capacity would be at least seven times as great as that of the engine power at present installed in the country for industrial purposes.

It appears then that, although the water power possibilities of the United Kingdom are small in comparison with those of some more favoured countries, they are by no means so negligible as is commonly supposed, even in comparison with the present industrial steam power resources of the country.

The capacity of the fuel power plants installed for industrial and public utility services in the United Kingdom in 1907 was approximately 9·8 million horse-power. Allowing for an increase of 15 per cent. since then, and an average load factor of 35 per cent., this is equivalent to 32,000 million horse-power hours per annum, or to a continuous 24-hour output of only 3·7 million horse-power.

According to Sir Dugald Clerk, the average consumption of coal per horse-power hour in this country is about 3·9 lb., which, on the above basis, would involve a total annual consumption of 55 million tons for industrial purposes, not including railways or steamships. This figure is in substantial agreement with the estimate of 60 million tons made for factory consumption in 1913 by the Coal Conservation Committee of the Ministry of Reconstruction, since this latter figure also includes coal used for heating and other manufacturing processes in factories.

Adopting this figure of 32,000 million horse-power hours as the annual demand for power for industrial purposes, it appears that the inland water power resources of the United Kingdom are capable of supplying about 27 per cent. of this, a proportion which, in such an industrial country as our own, is somewhat surprisingly large.

Many of the small powers would be well adapted for linking up, as automatic or semi-automatic stations, into a general network of electricity supply, or for augmenting the output of municipal supply works, as has been done so successfully, for example, at Chester, Worcester, and Salisbury.

The development of the many small schemes available in the Scottish Highlands would probably have a great effect on the social life of the community. It would go far towards reviving and extending those small local industries which should form an essential feature of the ideal rural township. Commercially such undertakings may appear to be of small importance, but as a factor in promoting the welfare of the State, economical and political, their influence can hardly be over-estimated.

Some of the larger schemes in Scotland would lend themselves admirably to transmission to its industrial districts, while others, in close vicinity to the sea board, would appear to be well adapted for supplying chemical, or electro-physical, or metallurgical processes.

There is a probability that at least two of these schemes will be developed in the near future. One of these—the Lochaber scheme—is capable of developing some 72,000 continuous horse-power, which is to be utilised largely in the manufacture of aluminium. It is interesting to note that when this scheme is completed the British Aluminium Corporation will have, with their station at Kinlochleven, an average continuous output of over 100,000 horse-power, and a maximum capacity of almost 140,000 horse-power.

The second—the scheme of the Grampian Power Company—is intended ultimately to develop upwards of 40,000 continuous horse-power, which it is proposed to use largely for general industrial purposes.

Should this latter scheme be carried to a successful conclusion it is likely to give an impetus to large scale water power development in Scotland. Its successful operation would, certainly lead to the development of others of the same type, which would help to provide a much needed home training ground for British hydro-electric engineers.

While this is admittedly an inopportune moment to suggest anything in the nature of State co-operation in such developments, it may be pointed out that many of the Scottish powers in particular occur in sparsely

* Delivered at the Edinburgh Meeting of the British Association, on September 9, 1921.

populated districts, and that, although they would ultimately become remunerative, the difficulty of raising the capital necessary for their development is great. In view of their direct and indirect advantages to the community it would appear not unreasonable to advocate that financial assistance should be granted by the State in the earlier stages of such developments. If such assistance, say in the form of a loan maturing after a period of ten or fifteen years, could be granted, it would certainly give an immediate impetus to the development of water power in this country.

Conservation.—The importance of water-power development from the point of view of conservation of natural resources requires no emphasis. When the value of coal purely as a chemical asset, or as a factor in the manufacture of such articles as iron and steel, cement, &c., is considered, its use as a fuel for power purposes, when any other equally cheap source of energy is available, would appear, indeed, to be unjustifiable.

The consumption of coal in the best modern steam plant of large size, giving continuous output, would be about 9 tons per horse-power year, and on this basis the world's available water power if utilised would be equivalent to some 1,800,000,000 tons of coal per annum. The world's output of coal in 1913 was approximately 1,200,000,000 tons, of which about 500,000,000 tons were used for industrial power purposes, so that on this basis 55,000,000 continuous water horse-power would be equivalent to the world's industrial energy at that date.

Not only does the use of water power lead to a direct conservation of fuel resources but it also serves to a notable degree to conserve man power. To take an extreme example, each of the 40,000 horse-power units now being installed at Niagara Falls will require for operation two men per shift. It is estimated that to produce the same power from a series of small factory steam plants, over 800 men would be required to mine, hoist, screen, load, transport by rail, unload, and fire under boilers the coal required, while, if account be taken of the additional labour involved in horse transport, wear and tear of roads and of railroad tracks and rolling stock, the number would be considerably increased. In the United States coal alone represents approximately one-third of the whole of the country's freight.

Uses of Hydro-Electric Energy.—While a large proportion of the energy developed from water power is utilised for industrial purposes and for lighting, power and traction, an increasing proportion is being used for electro-chemical and electro-metallurgical processes. It is probable indeed that we are only on the threshold of developments in electro-chemistry, and that the future demand for energy for such processes will be extremely large.

In Norway the electro-chemical industry absorbed 770,000 h.p. in 1918, or approximately 75 per cent. of the total output, as compared with 1,500 h.p. in 1910. Of this, some 400,000 h.p. were utilised in nitrogen fixation alone.

The production of electric steel in the United States of America increased from 13,700 tons in 1909 to 24,000 tons in 1914, and to 511,000 tons in 1918, this latter quantity absorbing 300,000,000 kw. hours, equivalent to almost 400,000 continuous horse-power.

In Canada, in 1918, the pulp and paper industry absorbed 450,000 h.p., or 20 per cent. of the total, while the output of central electric stations amounted to 70 per cent. of the total.

The electrification, on a large scale, of trunk line railways is also a probability in the not-distant future. In the United States of America, 650 miles of the main line of the Chicago, Milwaukee, and St. Paul Railway, comprising 850 miles of track, have been electrified, the power for operation being obtained from hydro-electric stations. In France, much of the track of the Compagnie du Midi in the region of the Pyrenees has been electrified with the aid of water power; much of the Swiss railway system has been electrified; and the electrification of many other trunk lines on the European continent is at present under consideration.

Quite apart from the probable huge demand in the distant future for energy for the manufacture of artificial fertilisers by some system of nitrogen fixation, agriculture would appear to offer a promising field for the use of hydro-electric power.

Much energy is now being utilised in the United States of America for purely agricultural purposes. In California, for example, there is in effect one vast system of electrical supply extending over a distance of 800 miles with 7,200 miles of high-tension transmission lines. This is fed from 75 hydro-electric stations, inter-connected with 47 steam plants, to give a total output of 785,000 h.p. A further group of 13 hydro-electric schemes now under construction will add another 520,000 h.p. A large proportion of this power is used in agriculture, and a census in 1915 showed that electric motors equivalent to over 190,000-h.p. were installed on Californian farms. The Californian rice industry is almost wholly dependent on irrigation made possible by electric pumping, while most of the mechanical processes involved in farming are being performed by electric power.

There can be little doubt that the economic development of many of our tropical dependencies is bound up in the development of their water-power resources. Not only would this enable railroads to be operated, irrigation schemes to be developed, and mineral deposits to be mined and worked, but it would go far to solve the black labour problem, which promises to be one of some difficulty in the near future.

While those outlets for electrical energy which are now in sight promise to absorb all the energy which can be cheaply developed for many years to come, there are many other probable directions in which cheap energy would find a new and profitable outlet. Among these may be mentioned the purification of municipal water supplies; the sterilisation of sewage; the dehydration of food products; and the preservation of timber.

Scope for Future Water-Power Development.—The figures already quoted indicate that the scope for inland water-power development throughout the world, and more particularly throughout the British Empire, is likely to be large for many years to come, and it is gratifying to know that British engineers are prepared to play a large part in such development work.

The utilisation of this water power is likely to give rise to some economic problems of interest and importance. When industrial conditions have again become stabilised, the competitive ability of the various nations will depend largely on economy in the application of energy to production and transportation, and the possession of cheap water powers is likely largely to counterbalance the possession of such resources as coal and iron as a measure of the industrial capacity of a nation.

While it is probably true in industrial communities that the most attractive water-power schemes have already received attention, many of those available in countries which have hitherto been non-industrial are capable of extremely cheap development and will certainly be utilised as soon as a market for their output can be assured.

It is in such countries that the result of these developments is likely to be most marked, and will require most careful consideration. Thus the hydro-electric survey of India now being carried out by the Indian Government indicates that very large water-power resources are available in the country, and that, although a few large schemes have been or are being developed, the resources of the country are practically untouched. There can be little doubt that in the course of time a large amount of cheap energy will be available in India for use in industrial processes, and as the country possesses a large and prolific population readily trained to mechanical and industrial processes, along with ample supplies of raw material for many such processes, all the conditions would appear to be favourable for its entry into the rank of manufacturing and industrial nations.

Modern Tendencies in Water-Power Development.—The large amount of attention which has been concentrated on the various aspects of water-power development during the past ten years has been responsible for great modifications and improvements in the design, arrangement, and construction of the plant.

Broadly speaking, these have been in the direction of increasing the size, capacity, reliability, and efficiency of individual units; of improving the design of the turbine setting and of the head and tail works; of increasing the rotative speed of low head turbines; of detailed modifications in the reaction type of turbine to enable it to operate under higher heads than have hitherto been considered feasible; and of increasing the voltage utilised in transmission.

The capacity of individual units has been increased rapidly during recent years, and at the present time units having a maximum capacity of 55,000 horse-power under a head of 305 feet are being installed in the Queenston-Chippawa project at Niagara, while units of 100,000 horse-power are projected for an extension of the same plant.

These modern high power turbines are usually of the vertical shaft, single runner type, with the weight of the shaft, runner, and generator carried from a single thrust of the Michell type. This type lends itself to a simple and efficient form of setting, while the friction losses in the turbine are extremely low. As a result of careful overall design it has been found possible to build units of this type having an efficiency of approximately 93 per cent.

One of the great drawbacks of the low head turbine in the past has been its relatively slow speed of rotation, which necessitated either a slow speed, and consequently costly generator or expensive gearing. As a result of experiment it has, however, been possible so to modify the form of the runner as greatly to increase the speed of rotation under a given head without seriously reducing the efficiency.

Investigations in this direction are still in progress and promise to give rise to important results. At the present time, however, turbines are in existence which are capable of working efficiently at speeds at least five times as great as would have been thought feasible ten years ago.

The provision of a suitable pipe line has, until recent years, tended to retard the development of plants for very high heads. Under such heads the necessary wall thickness, even with a moderate pipe diameter, becomes too great to permit of the use of riveted joints. Recent developments in electric welding and oxy-acetylene welding have, however, rendered it possible to construct welded pipes, and by their aid, and by the use of solid drawn steel pipes in extreme cases, it has been found possible to harness some very high falls. The highest as yet utilised is at the Fully installation in Switzerland. Here the working head is 5,412 ft., corresponding to a working pressure of 2,360 lb. sq. in. The pipe line is 19·7 in. in diameter and 1¼ in. thick at its lower end, and each of the three Pelton wheels in the power house develops 3,000 h.p., with an efficiency of 82 per cent.

Until comparatively recently the Pelton wheel was looked upon as the only practicable turbine for high heads, and the use of the Francis turbine was restricted to heads below about 400 ft. This was due partly to the fact that a reaction turbine of comparatively small dimensions gives a large output under a high head, and except in turbines of comparatively large power the water passages become very small, and the friction losses in consequence large.

A further and more important reason for the general choice of the Pelton wheel for high heads was the fact that in the earlier Francis turbines, when operating under heads involving high speeds of water flow, corrosion of the runner was very serious. This corrosion is now generally attributed to the liberation of air containing nascent oxygen, at points where eddy formation causes regions of low pressure. Careful design of the vanes has enabled this to be largely prevented in modern runners, and in consequence the field of useful application of the Francis turbine has been extended until at present turbines of this type are operating successfully under a head of 850 ft., and this limit will probably be exceeded in the near future.

The great increase in all constructional costs since 1914 has increased the cost of the average hydro-electric plant by something of the order of 150 per cent., and since the cost of energy produced by such a plant is mainly due to fixed charges on the capital expenditure, this cost has gone up in an even greater proportion owing to the higher interest charges now demanded.

It is true that the same increased cost applies within narrow limits to the output from every steam plant erected since the war, and the relative position of the two types of power plant with coal at 25s. per ton, is much the same as before the war.

The fact remains, however, that a newly-constructed hydro-electric plant has often to compete in the market with a steam plant built in pre-war days, whose standing charges are comparatively low, and in order to enable it to do so with success the constructional cost must often be reduced to a minimum compatible with safe and efficient operation. With this in view many modifications in design and construction have been introduced in recent plants, but there would still appear to be ample scope for investigation into the possibility of reducing the first cost by modifying many of the details of design and methods of construction now in common use.

Among recent modifications in this direction may be mentioned:—

1. The elimination of the dam in storage schemes in which natural lochs or reservoirs are utilised, this water level being drawn down in times of drought instead of being raised in times of flood. This reduces the cost of construction appreciably in favourable circumstances, and eliminates the necessity for paying compensation for flooding of the land surrounding the reservoir.

2. The substitution, where feasible, of rock-fill dams for those of masonry or monolithic concrete.

3. The introduction of outdoor installations with the minimum of power house construction.

4. The simplification of the power plant.

Some progress has already been made in these directions, and it is probable that experience based on recent installations and experimental investigations will enable considerable further progress to be made.

Research in Hydro-Electric Problems.—There are few branches of engineering in which research is more urgently required and in which it might be more directly useful.

Among the many questions still requiring investigation on the civil and mechanical side may be mentioned:

1. *Turbines.*—Investigation of turbine corrosion as affected by the material and shape of the vanes.

Effect of erosion due to sand and silt.

Resistance to erosion offered by different materials and coatings.

Bucket design in low head high-speed turbines.

Draft tube design.

Investigation of the directions and velocities of flow in modern types of high-speed turbines.

Investigation of the degree of guidance as affected by the number of guide and runner vanes.

2. *Conduits and Pressure Tunnels.*—The design of large pipe lines under low heads with a view to reduce the weight of metal. The investigation of anti-corrosive coatings, so as to reduce the necessity for additional wall thickness to allow for corrosion.

Methods of strengthening large thin walled pipes against bending and against external pressures.

Methods of lining open canals and of boring and lining pressure tunnels.

Effects of curvature in a canal or tunnel.

3. *Dams.*—Most efficient methods of construction and best form of section, especially for rockfill and earthen dams. Best methods of producing water tightness.

4. *Run-off data.*—Since the possibility of designing an installation to develop the available power efficiently and economically depends in many cases essentially on the accuracy of the run-off data available, the possession of accurate data extending over a long series of years is of great value.

While such data may be obtained either from stream gaugings or from rainfall and evaporation records, the former method is by far the more reliable. For a reasonable degree of accuracy, however, records must be available extending over a long period of years, and at the present moment such data are available only in very few cases.

Where accurate rainfall and evaporation records are available, it is possible to obtain what is often a sufficiently close approximation to the run off, but even rainfall records are not generally available where they are most required, and even in a district where such records are available, they are usually confined to easily accessible points, and are seldom extended to the higher levels of a catchment area where the rainfall is greatest. Even throughout the United Kingdom our knowledge of the rainfall at elevations exceeding 500 ft. is not satisfactory, and little definite is known concerning that at elevations exceeding 1,000 ft.

In this country evaporation may account for between 20 per cent. and 30 per cent. of the annual rainfall, depending on the physical characteristics of the site, its exposure, mean temperature and the type of surface covering. In some countries evaporation may account for anything up to 100 per cent. of the rainfall. As yet, however, few records are available as to the effect of the many variables involved. An investigation devoted

to the question of evaporation from water surfaces, and from surfaces covered with bare soil and with various crops, under different conditions of wind, exposure and mean temperature, would appear to be urgently needed. If this could be combined with an extension of Vermeulle's investigation into the relationship between rainfall, evaporation and run-off on watersheds of a few characteristic types, it would do much towards enabling an accurate estimate of the water power possibilities of any given site to be predetermined.

Even more useful results would follow the initiation of a systematic scheme of gauging applied to all streams affording potential power sites.

Among other questions which are ripe for investigation may be mentioned :—

1. The combined operation of steam and water power plants to give maximum all-round efficiency.

2. The relative advantages of high voltage, D.C. and A.C. generation and transmission for short distances.

3. The operation of automatic and semi-automatic generating stations.

Tidal Power.—The question of tidal power has received much attention during the last few years. In this country it has been considered by the Water Power Resources Committee of the Board of Trade, who have issued a special tidal power report dealing more particularly with a suggested scheme on the Severn. The outline of a specific scheme on the same estuary was published by the Ministry of Transport towards the end of 1920.

In France a special commission has been appointed by the Ministry of Public Works to consider the development of tidal power, and it has been decided to erect a 3,000 kw. experimental plant on the coast of Brittany. With a view to encouraging research the Government proposes to grant concessions, where required, for the laying down of additional installations.

The tidal rise and fall around our coasts represents an enormous amount of energy, as may be exemplified by the fact that the power obtainable from the suggested Severn installation alone, for a period of eight hours daily thoughout the year, would be of the order of 450,000 h.p.

Many suggestions for utilising the tides by the use of current motors, float-operated air compressors and the like, have been made, but the only practicable means of utilising tidal energy on any large scale would appear to involve the provision of one or more dams, impounding the water in tidal basins, and the use of the impounded water to drive turbines.

The energy thus rendered available is, however, intermittent ; the average working head is low and varies daily within very wide limits, while the maximum daily output varies widely as between spring and neap tides.

If some electro-chemical or electro-physical process were available, capable of utilising an intermittent energy supply subject to variations of this kind, the value of tidal power would be greatly increased. At the moment, however, no such process is commercially available, and in order to utilise any isolated tidal scheme for normal industrial application it is necessary to provide means for converting the variable output into a continuous supply constant throughout the normal working period.

Various schemes have been suggested for obtaining a continuous output by the co-ordinated operation of two or more tidal basins separated from each other and from the sea by dams with appropriate sluice gates. This method, however, can only get over the difficulty of equalising the outputs of spring and neap tides if it be arranged that the maximum rate of output is that governed by the working head at the lowest neap tide, in which case only a small fraction of the available energy is utilised.

When a single tidal basin is used it is necessary to provide some storage system to absorb a portion of the energy during the daily and fortnightly periods of maximum output, and for this purpose the most promising method at the moment appears to involve the use of an auxiliary high level reservoir into which water is pumped when excess energy is available, to be used to drive secondary turbines as required. It is, however, possible that better methods may be devised. Storage by the use of electrically-heated boilers has been suggested, and the whole field of storage is one which would probably well repay investigation.

If a sufficiently extensive electrical network were available, linking up a number of large steam and inland water power stations, a tidal power scheme might readily be connected into such a network without any storage being necessary, and this would appear to be a possibility which should not be overlooked in the case of our own country.

Investigation Necessary.—A tidal power project on any large scale involves a number of special problems for the satisfactory solution of which our present data are inadequate.

Thus the effect of a barrage on the silting of a large estuary, and the exact effect on the level in the estuary and in the tidal basin at any given time can only be determined by experiment, either on a small installation, or preferably on a model of the large scheme.

Many of the hydraulic, mechanical, and electrical problems involved are comparatively new, and there is little practical experience to serve as a basis of their solution.

Among these may be mentioned :—

(1) The most advantageous cycle of operations as regards working periods, mean head, and variations of head.

(2) The methods of control and of sluice gate operation.

(3) Effect of changes of level due to wind or waves.

(4) The best form of turbine and setting and the most economical turbine capacity.

(5) The possibilities of undue corrosion of turbine parts in salt water.

(6) The best method of operation ; constant or varied speed.

(7) Whether the generators shall be geared or direct driven.

(8) Whether generation shall be by direct or alternating current.

The questions of interference with navigation and with fisheries ; of utilising the dam for rail or road transport across the estuary ; and, above all, economic questions connected with the cost of production, and the disposal of the output of such an installation, also require the most careful consideration before a scheme of any magnitude can be embarked upon with assurance of success.

In view of the magnitude of the interests involved, and of the fact that rough preliminary estimates indicate that to-day current even for an ordinary industrial load could be supplied from such an installation at a price lower than from a steam generating station giving the same output with coal at its present price, it would appear desirable that these problems should receive adequate investigation at an early date.

Facilities for Research in Hydraulic and Cognate Problems.—In view of the considerations already outlined, and especially in view of the large part which British engineering will probably play in future water power developments, the provision on an adequate scale at some institution in this country of facilities for research on hydraulic and cognate problems connected with the development of water power is worthy of serious attention.

At present the subject is treated in the curriculum of the engineering schools of one or two of our Universities, but in no case is the laboratory equipment really adequate for the purpose in question.

What is required is a research laboratory with facilities for doing experiments on the flow of water on a fairly large scale ; for carrying out turbine tests on models of sufficient capacity to serve as a basis for design, and, if possible, working in conjunction with one or more of the hydro-electric stations already in existence, or to be installed in the country, at which certain large scale work might be carried out.

The provision of such a laboratory is at the moment under consideration in the United States, and in view of the rapidity with which the designs of hydraulic prime movers and their accessories are being improved at the moment, it would appear most desirable that the British designer, in order that the deservedly high status of his products should be maintained and enhanced, should at least have access to equal facilities, and should, if necessary, be able to submit any outstanding problems to investigation by a specially trained staff.

The extent to which our various heat engine laboratories have been able of recent years to assist in the development of the internal combustion engine, and to which our experimental tanks have assisted in the development of the shipbuilding industry, is well known to most of us, and the provision of similar facilities to assist in the development of our hydro-electric industry would probably have equally good results in this connection.

As a result of representations made by the Water Power Committee of the Board of Trade, I understand that it has now been decided to initiate a Chair of Hydro-Electric Engineering in some one University, and it is greatly to be hoped that funds may be available to enable the necessary laboratory to be designed and equipped on a scale commensurate with the importance of the work which it would be required to undertake.

THE NEW ELECTRICITY SUPPLY STATION OF THE EDINBURGH CORPORATION.*

Some Notes on the New Electricity Supply Station of the Edinburgh Corporation for the Supply in Bulk to the City and to the Lothian.

By S. B. DONKIN.

IN 1891 the Corporation obtained a Provisional Order from the Board of Trade to enable them to supply electricity in the burgh. A site for a power station was acquired at Dewar-place, and on April 11, 1895, the Corporation commenced to give a supply of electricity. The growth of the electricity supply undertaking was rapid, and the Dewar-place station was extended from time to time until 1899, when it was found necessary to build a new station at McDonald-road, as there was no room for further plant at Dewar-place. The McDonald-road station was extended also from time to time until its present buildings were completely filled with generating plant in the winter of 1912–13.

It was found that the limits of distribution direct from the existing generating stations had been practically reached. It was therefore economically desirable for any new plant, or new generating station, to produce high-tension three-phase alternating current, which could be distributed by means of less costly feeders to various sub-stations in the supply area. The Corporation decided that a new site should be acquired, and a station erected to generate high-tension three-phase current at the sea-side at Portobello. The Westbank site at Portobello was only 25 ft. above the sea level, and was actually adjacent to the sea shore. There was sufficient space for a generating station having an ultimate capacity of 100,000 kw., and there were adjacent sites which could be utilised for coal sidings or by-product recovery plant, which could be obtained if required.

On June 30, 1919, the Board of Trade (now the Electricity Commissioners) allowed the work of the Portobello station to be proceeded with, with special reference to the necessity of conceiving it on a large scale for bulk supply. Three 10,000-kw. turbo-alternator sets were to be installed with requisite boiler plant, &c. Since the passing of the new Electricity Act of 1919, the Electricity Commissioners have had before them the question of the area to be supplied from the Portobello Power Station. An application has been submitted to them indicating the views of the Corporation on this matter. The area suggested in the application is that roughly indicated on the map shown in the Fig. 1, on page 423. Roughly speaking the area is bounded by Linlithgow and Bathgate on the west, by North Berwick or Dunbar on the east, and by Penicuik and Gorebridge on the south.

Details of Power Station. Fig. 2, on page 423, shows the Westbank site for the Portobello station, together with the sites immediately adjacent thereto that have been purchased by the Corporation for use in connection with the electricity undertaking when required. Site "A" was acquired to enable coal sidings to be put on it in sufficient quantity to satisfy the requirements of the railway company, and to enable the Corporation to have room to erect gas producing and by-product recovery plant should the raising of steam from coal by such a process prove at any time in the future to be economically sound. It was further acquired so as to enable parts of the clay pit to be filled up by ash refuse from the power-house when it is in operation.

The general arrangement of the power station on the Westbank site, together with the sidings, and sea water connections for condensing purposes, are shown in Fig. 3, on Plate XXI. Cross sections of the station and details of the sea-water tunnels are given in Figs. 4 to 6. Coal is brought on to the sidings provided on the clay pit site, and the trucks will be emptied by means of a rotary tippler into a hopper below ground level. This hopper feeds a belt conveyor running in a tunnel from the clay pit site to the power-house site. On the power-house site this conveyor will discharge the coal on to another belt conveyor, which in turn discharges it into hoppers feeding gravity bucket conveyors, which carry the coal into the bunkers over each boiler-house. The belt conveyor from the clay pit site can also tip the coal into a store on the site, from which a travelling jib crane can grab it, and distribute and store it over the power-house site. This jib crane can also collect the coal from the site and discharge it into the hoppers feeding the gravity bucket conveyors. The coaling plant is being provided by the Mitchell Conveyor and Transporter Company and by Messrs. Fraser and Chalmers.

The boilers are of the Stirling Boiler Company's tri-drum type with superposed steel tube economisers. Three types of stokers will be adopted, the Babcock and Wilcox chain grate, the Erith Riley grate and the Underfeed Stoker Company's self-contained travelling grate, all fitted with forced and induced draught fans driven by motors. The steam pressure will be 300 lb. per square inch and the total temperature will be 700 deg. F. Six boilers are being provided at present, two being able to provide sufficient steam for one 10,000 kw. turbo-alternator.

The turbo-alternators are of Messrs. Brown, Boveri and Co.'s manufacture, and the condensing plant is made by Messrs. W. H. Allen, Sons and Co. As already mentioned there are three sets, each of 10,000 kw. normal output, but each having a maximum continuous rating of 14,700 kw. A 70-ton travelling crane is provided in the turbine house, made by Messrs. Marshall, Fleming and Co., and the high-tension switchgear is all being provided by the British Thomson-Houston Company.

The whole of the steelwork for the buildings has been carried out by Messrs. Redpath, Brown and Co., of Edinburgh, and the building superstructure work by Messrs. J. Angus and Sons.

The plant for the station, which is at present on order, is such that at normal full load the overall thermal efficiency of the station should be 21 per cent., the coal consumption being equal to an expenditure of 16,300 B.Th.U. per kilowatt hour. Mechanical appliances have been introduced to a considerable extent in the station, in which connection it is desirable to bear in mind that a labourer earns, at the present time, very nearly 4*l.* per week. If we call this figure the equivalent of 200*l.* per annum, and capitalise this salary at 10 per cent., it is obvious that if we can purchase any mechanical refinement or apparatus which saves the employment of one man for less than 2,000*l.*, we can show a saving in the cost of operation. It will be noted that short chimneys are used. These are fitted with dust catchers. As compared with tall brick chimneys these short chimneys save capital expenditure, and the fan arrangement gives extreme nicety of draught and air regulation. Views of the station during erection are given in Figs. 11 to 13 on Plate XXII.

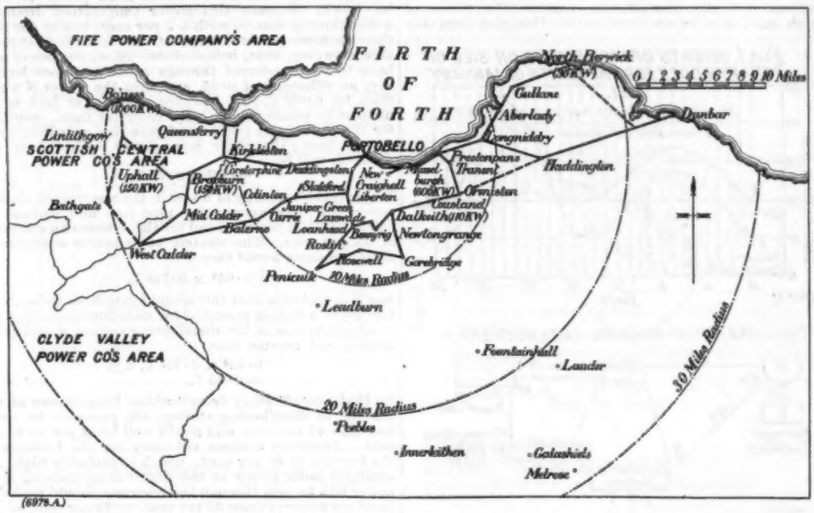
The boiler plant is partly illustrated in Figs. 7 and 10, on Plate XXI. It is proposed to control the boilers from instruments in cabins in a central overhead gangway in the boiler-house. The positions of these cabins are shown in Figs. 7 to 10. The shift engineer is to control the economic performance of the boilers, and the firemen have only to carry out instructions. The boiler-house plant is that which if worked properly can produce greater savings than any other portion of a steam power station. Want of knowledge of what is happening during the process of burning coal and raising steam may cause bad operation and uneconomical working. The cabins will contain all the necessary recording instruments to enable daily analyses of operation to be made.

The system of boiler-house control is based on the schemes devised by M. Myers, of Sheffield. The instruments necessary for the general control of a boiler-house have been divided into two main groups—the recording instruments and the indicating instruments. The former

* Paper contributed to Section G of the British Association at Edinburgh, September, 1921.

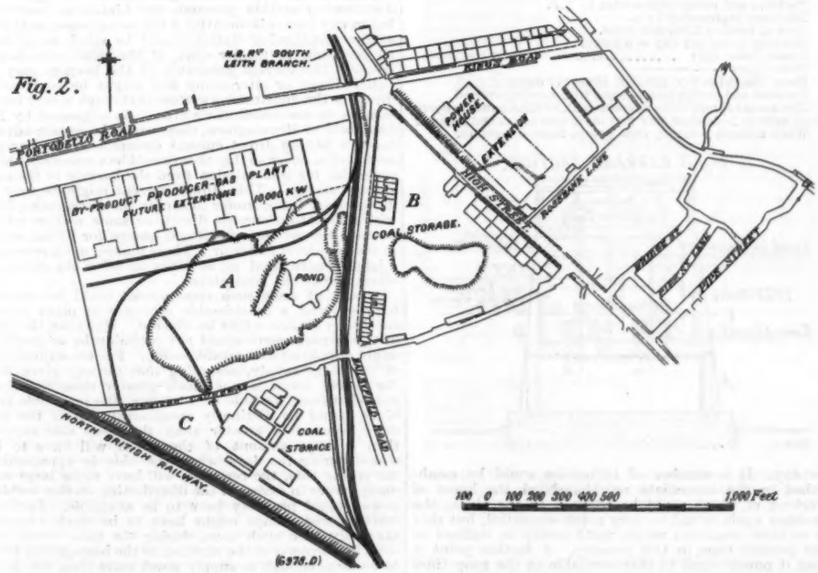
are placed in a specially built cabin (one cabin for every two boilers), and the latter collected wherever possible on one board and placed in a convenient position in front of each pair of boilers. The set of recording instruments for each respective boiler will be situated on one wall of the cabin nearest the boiler to which they belong. The following instruments are proposed for each boiler :—

Indicators.	*Recorders.*
1. Steam flow meter indicator	Ditto recorder with chart.
2. Feed-water meter indicator	Ditto recorder with chart.
3. Coal meter	Ditto recorder with chart.
4. CO_2 indicator	Ditto recorder with chart.



(6978.A)

FIG. 1.



(6978.D)

Indicators.	*Recorders.*
5. Draught gauge indicator for forced and induced draught	Ditto recorders with chart.
6. Steam pressure gauge ...	Pressure gauge recorder with chart.
7. Steam temperature indicator	Steam temperature recorder with chart
8. Differential draught gauge connected above and below each grate	Recording thermometers in economiser inlet, economiser outlet on water side and on flue gas side.

Generally for each group of boilers in one boiler-house there will be : One blow-down recorder with chart ; one densimeter for the blow-down ; one feed-water recording thermometer.

For every group of two boilers feeding one turbine there will also be, on the indicator board beside the two boilers, a kilowatt meter to indicate the load on the turbine fed by these two boilers. The coal consumption indicator and recorders are proposed to be of the type introduced by the Lea Recorder Company, and will measure the rate of flow of coal passing on to any grate in a given time with means of adjusting the ratio of weight to volume to suit any type of coal in use. There will be a telephone in one of the cabins in each boiler-house which will be connected to the main switch control room, in order to put each boiler-house into direct communication with the switchboard. There will also be a signal in each boiler-house which will be worked from the main switch control room. A bell will be provided in each cabin to draw the attention of the boiler attendants to the boiler-house shift engineer, who can then communicate his orders through the window provided in each cabin for that purpose.

It is proposed to de-gas the condensate plus the make-up water. Taking out all oxygen from the water will render internal corrosion of boilers or economisers improbable. Air leaks in at turbine shaft glands, condenser joints and pumps, but any CO_2 present will not be harmful in the absence of oxygen. It is perhaps necessary to mention again that full provision has been made for the possible adaptation in the future for the carbonisation of the coal and the use of by-product recovery plant. This can be undertaken without much alteration to the boiler plant and can be advised whenever it is possible to undertake the additional expenditure. At present it is not profitable.

A diagram of the sea connections and pump lines is given in Fig. 15, annexed. The track of the water from the sea through the pumps and condensers and back to the sea can be traced from this figure. As will be seen from the connections and valves, any tunnel may be used either for suction or discharge. Normally two tunnels will be suction and one discharge giving twice the velocity of exit as of entry. Details of the sea work, shafts and tunnels are given in Figs. 16 to 19 on Plate XXIII and 24 to 28 on Plate XXIV. The strainers in the land shafts are fitted to prevent the entry of fish or seaweed and can be washed clean at intervals by reversing the flow and changing over from suction to discharge. This washes all collected material back to the sea. The whole sea-water system is syphonic, as will be clear from the cross-section given in Fig. 29, on Plate XXIV, and only heads above syphonic heads have to be pumped against, including friction. It is later proposed that further tunnels and pipes shall be installed, as shown in Fig. 30, Plate XXIV. Details of the sea water pump house are shown in Figs. 34 to 40.

The system adopted of running subterranean tunnels out to sea for taking the sea water into the station and carrying it back to the sea requires some explanation. Experience had been gained in the past on the banks of the River Thames in carrying out somewhat similar tunnel schemes, and also of laying pipes from the surface and supporting these pipes partly on foundations, and partly submerged under the foreshore of the river. This experience proved that the cost of the tunnelling scheme was less than the cost of laying pipes down the foreshore into the

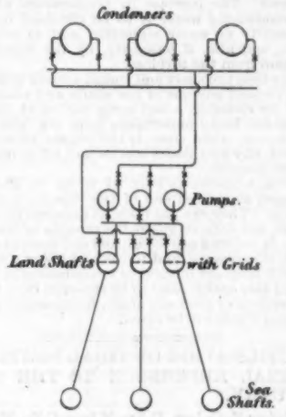


FIG. 15.

water, because so much of the system had to be carried out below low-water tide level, and this could only be done by means of a dam to keep the water back while the work of construction and laying of the pipes was being carried out.

The possibility of constructing a light jetty and carrying the pipes going to and from the sea along the jetty and turning these pipes down into the sea below low-water mark at sufficient distance out from the shore was also considered for Edinburgh. It was estimated that this scheme came to nearly three times the cost of the tunnelling scheme. The actual cost of the tunnelling work shown in the figures, and now under construction, works out at 28*l.* per yard run of the tunnel, excluding the cost of the shafts. The reason for this comparative cheapness is the fact that the work can be proceeded with without interference from the weather or from the sea.

The sea work shafts and tunnels are being carried out by Messrs. C. Brand and Son, of Glasgow, and Mr. H. H. Dalrymple Hay has been the joint engineer with Sir Alexander Kennedy and the author in connection with this part of the work. The work was undertaken generally in the following manner : The three land shafts were first sunk to their required depth and completed with their concrete bases. From the bottom of these shafts the tunnels were driven. The subsoil at the level of the tunnels consists entirely of boulder clay, and two of the tunnels have been completed and the junction made with the sea shafts without any necessity for working with compressed air. In the third tunnel some porous seams of sand have been encountered near the sea end of the tunnel and in sinking the sea shaft. A considerable delay has occurred in consequence, as it involves the use of compressed air. Fig. 20 shows men at work on the tunnel face. In sinking the shafts at the sea end of the tunnels considerable works were involved. The foreshore is covered with a layer of sand some 15 ft. thick, and under this lies the boulder clay into which the tunnels are driven. In order to ensure a satisfactory seal in the boulder clay for the sea shafts, the sand was dredged, and in one case a rectangular shield and in the other case a circular cylinder larger than the actual shaft was lowered into the hole so as to rest on the boulder clay. These cylinders or shields are shown in Figs. 21 and 22. The shafts were built up on temporary wooden stagings and lowered ring by ring into position inside these shields until the top reached a level some feet above high tide. The annular space between the shield and the shaft was then packed with clay and clay bags in alternate layers and rammed tight. The shafts were then loaded and a diver worked at the base with water jets until the shaft sank a few feet into the boulder clay and became water sealed. The water inside could then be pumped out and the shafts completed in a downward direction by underpinning until each was completed. Fig. 23 shows one of the sea shafts with its temporary staging.

The whole of that portion of each sea shaft above the level of the sea bed will be removed finally and a machined face of gunmetal left at the top on to which a sealing cap can be lowered when necessary. Fig. 14 shows the workings round and at the land shafts during their construction, and shows the fan and duct used for ventilating the tunnels ; the air duct was carried up to a few feet of the working face of the tunnel.

Since the commencement of the sea work, means of preventing the accumulation of mussels on the inside of the sea shafts, and of the tunnels, have been investigated.

Research work on the subject is being carried out for the Corporation by Dr. Ritchie, of the Edinburgh Museum, on the best means of preventing the formation of mussel spat in these shafts and tunnels. We have obtained as much information as possible from the Harbours and Fisheries Branch of the Board of Agriculture, and from various other marine biological experts in this country. We believe that Dr. Ritchie will, by the end of this season, be able to advise us definitely what the best cure will be, that is of a practical and useable nature.

The probable solution is to raise the temperature of the outgoing water to such a degree, possibly to 120 deg. F., which will, it is believed, be found to kill the mussel spat in a few minutes. Such increase in temperature being made once a day or less during the spatting season, which may last a month or two. Other possible alternatives are under consideration, but it is obvious that only a system that is cheap in operation can be considered. The increase in temperature of the outgoing condensing water is to be obtained by reducing the quantity of water circulated and so reducing the vacuum, and also, if necessary, by the introduction of bled steam from the turbines.

In any case the shaft and tunnel system is designed so that at present any one of the shafts and tunnels can be laid off for cleaning, a cap being put on at the sea end, the cleaning being undertaken from the land end, and, in the future, when there is the duplex system already described, any two shafts can be laid off at one time for the same purpose.

Beacons, as shown in Figs. 31 to 33, on Plate XXIV, are erected at the sea end of the tunnels, and over the sea shafts. They are put there as required by the Board of Trade, not only to guard the mouths of these shafts, but also to enable a cap to be lifted and lowered for sealing the end, if necessary, and to lift and lower a coarse grid which will keep out bathers or sea monsters of any kind. They will also enable sand to be removed from the pocket at the bottom of each sea shaft, by means of a grab and winch gear which will be fitted.

THE UTILISATION OF TIDAL POWER, WITH SPECIAL REFERENCE TO THE SEVERN ESTUARY.*

By Professor F. C. LEA, D.Sc., M.Inst.,C.E., M.I.Mech.E.

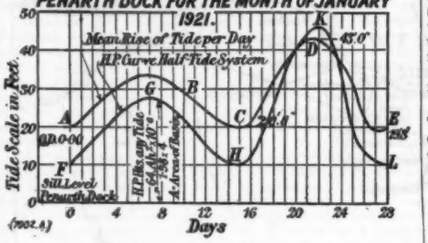
SUGGESTIONS have frequently been made that the tidal power available in the tidal estuaries of this country might be utilised, and thus a considerable saving in the demand upon our coal supplies might be effected. These suggestions are by no means new. The rising waters of estuaries have been impounded and utilised for power production, on a small scale, in various parts of the world for many years and power for various purposes has thus been obtained. Whether the suggestion is an economically sound one, to use, for example, the available power in the River Severn, may be seriously open to question, and whether the power could be produced at a rate that would compete with that produced in some stations that, at present, exist or that might possibly be constructed in the near future, can only be answered after a very full inquiry, not only of the probable cost of the civil engineering works involved in utilising the tides, but also the possible market for the energy within a reasonable distance of the area within which it is produced. It has been suggested that a barrage should be constructed across the River Severn near the junction of the Wye and the Severn for the purpose of power production, and incidentally to improve the means of communication in the neighbourhood, and that the power thus produced might be utilised not only in the immediate vicinity of the barrage, but that it also might be transmitted to London, Birmingham and other areas.

There would appear to be no fundamental difficulty in transmitting the power electrically, but whether it can be transmitted economically, and at such a price per unit as will compare favourably with the present cost of power per unit in those neighbourhoods, is a somewhat difficult question. It is a question that might reasonably be discussed in such a gathering as this, but this paper is confined to a brief discussion of the hydraulic problem involved in the utilisation of the power of the tides of such an estuary as the River Severn. Since the last meeting of the British Association, definite proposals have been put forward by the Ministry of Transport, which practically embody those made by Messrs. Addenbrooke, Meik and Twinberrow, when giving evidence before the commission of inquiry on available sources of water power. The proposals are related, in this particular case, to the developing of improved means of communication of the neighbourhood, and thus the suggested barrage across the Severn would serve the double purpose of impounding the tides and conveying traffic across this very difficult barrier to communication between the counties on the west and north of the Severn and those on the east and south.

It is well known that the range of tides of the River Severn is very much higher than in any other estuary round the coast of Great Britain, and it would appear therefore, with the other conditions at all equal, that it would be particularly suitable as a source of power production. In the neighbourhood of the junction of the Wye and the Severn, the rise of the spring tides is at times about 50 ft. If such a rise could be depended upon day by day throughout the year, the amount of power available would be very large indeed, and there is every probability that it could be used economically. The neap tides, however, may be as low as 16 ft. The problem is furthermore complicated by the fact that during any month there are two minimum values of the neap tides and two maximum values of the spring tides. For example, Fig. 1 shows the daily rise for every day for the month of January, 1921, for a point on the River Severn not far removed from the proposed site. It will be seen that the range during the month passes over two maximum and two minimum values, but the two maximum ranges are not by any means equal. It will be seen later, as might at once be anticipated, that the available power on any particular day will depend upon the rise of the tide on that particular day. If the demand made is not greater than that which can be supplied by the neap tides, then for each day throughout the year a certain horse power will be available which will be much smaller than the mean horse-power that could be obtained from the estuary.

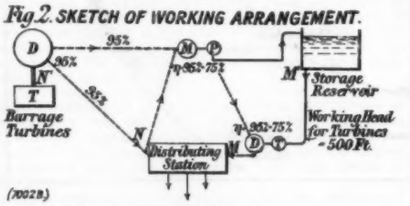
From certain points of view, therefore, the problem would be made easier if the demands made upon the estuary were not greater than could be supplied by the neap tides. Here, again, however, another serious difficulty immediately arises. The times of high and low tides are continuously changing from day

Fig. 1. HEIGHTS OF HIGH WATER ON SILL OF PENARTH DOCK FOR THE MONTH OF JANUARY 1921.



(1922.4)

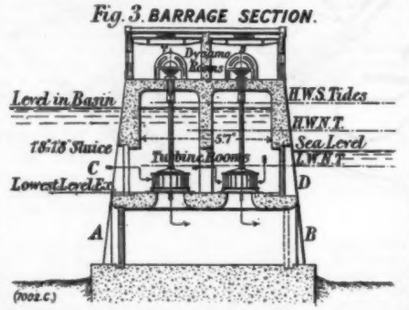
Fig. 2. SKETCH OF WORKING ARRANGEMENT.



(1922.8)

Motors and dynamos represented by M.D.
Turbines and pumps represented by T.P.
Efficiency represented by η.
Area of basin = 25 square miles.
Working period per day = 6 hours.
Transmission lines .....
Water pipes ——
Mean demand = 5×10^6 H.P. hours per day.
Turbines and pumps may be same with motion reversed.
The motors M may drive alternators D, or when power delivered from barrage > demand they may drive alternators and pumps P. When demand > supply then pumps become turbines.

Fig. 3. BARRAGE SECTION.



(1922.C)

to day. If a number of industries could be established in the immediate neighbourhood, the hours of working of which could be adapted to the tides, the problem again would be very much simplified, but that is an ideal condition which could hardly be realised at the present time in this country. A further point is that if power equal to that available at the neap tides only is to be taken from the estuary, the cost of the barrage in proportion to the amount of power available will be very high indeed. On the other hand, if power greater than that available at the neap tides is to be utilised, or if the power equal to that of the neap tides is to be available at hours suited to the needs of industries rather than at the times suited to the tides, large storage capacity is essential, of either an electrical or hydraulic character. Whether large storage of electrical power can be economically effected is probably open to question unless new forms of large capacity storage batteries can be developed. The storing of power hydraulically means clearly a large expenditure on civil engineering works and also on hydraulic plant. Turbines will be required in the barrage to generate electrical power at times controlled by the tides. This would have to be used, partly to supply the demand and partly to drive electrically-driven pumps for raising the water to a suitable storage reservoir; the water in this reservoir could be utilised at will to drive other turbines for the production of electrical power to supply the demand made by the distributing station. It might be quite possible to make centrifugal pumps to raise the water to the impounding reservoir reversible so that they could be utilised as turbines when necessary.

The use of the high level reservoir, however, to supply hydraulic power as the demand arises, can only be effected at the expense of very considerable losses in the system. Providing the capacity of this reservoir is large enough, it can be used to give for the lunar period a steady daily supply during any time in the day, even though the energy supply is very variable, and it can clearly also be used to store energy produced during any given hours in the day for use at any other period. Let Fig. 2 be the diagrammatic scheme for barrage, reservoir, and subsidiary electric distributing station from which N horse-power hours per day are required. No attempt is made in the diagram to differentiate correctly the losses; they may differ by 10 per cent. from what has been assumed. Let the horse-power of the turbines at the barrage be T, then the electrical horse-power N_1 may be $0 \cdot 95$T. Suppose this power transmitted direct to a distributing station with a 5 per cent. loss in the line, then the horse-power N may be $0 \cdot 95^2$ T. It is most probable, however, that, before distribution, the power may have to be transferred through other machines having say, an efficiency of $0 \cdot 95$, and thus the power N would then be $0 \cdot 95^3$T. If, however, the power had to be utilised to pump water to the reservoir then, assuming for the centrifugal pumps and pipe line an efficiency of 75 per cent., the water horse-power delivered to the reservoir will be

$$0 \cdot 95^2 \times 0 \cdot 75 \text{ T.}$$

To convert the energy of water in the reservoir to electric energy we may assume for pipe line and turbine an efficiency of 75 per cent. and for the dynamo an efficiency of 95 per cent. The electric horse-power available at these dynamos would then be

$$0 \cdot 95^3 \times 0 \cdot 75^2 \text{ T,}$$

and it is probable that this would again have to be transformed to a higher potential for distribution so that the available power at the distributing station would probably be not greater than

$$0 \cdot 95^4 \times 0 \cdot 75^2 \text{ T. h.p.}$$
$$= 0 \cdot 45 \text{ T.}$$

So that the efficiency from turbine horse-power at the barrage to distributing station will probably be much less than 45 per cent. and might well be as low as 40 per cent. Assuming a mean efficiency for the turbines at the barrage of 80 per cent., which is probably high, the available horse-power at the distributing station, if all power had to pass through the reservoir, would probably be of the order of from 32 per cent. to 38 per cent. of the available tidal power. It would not, however, be essential that all the power should pass from the barrage to the distributing station through the high-level reservoir, but in any case it is doubtful if the mean power available at the distributing station would be much more than 50 per cent. to 60 per cent. of the tidal water-horse-power. The current generated at the barrage may be either direct or alternating and might be sent either direct to the distributing system or through rotary transformers to the distributing lines. As suggested by Mr Chattock, of Birmingham, there would be certain advantages in having direct current dynamos in the barrage arranged in series so that there would be a reasonably high potential for transmission from the barrage to the subsidiary station. This direct current might be used to drive rotary transformers to supply the distributing lines with alternating current direct, or some motors might be used for driving centrifugal pumps for lifting water to the high-level reservoir. These pumps, when reversed, might then be used as turbines to drive the rotors as alternate-current generators.

Clearly, if some such arrangement could be successfully adopted, a considerable economy in plant at the subsidiary station might be effected. However, the gain in this arrangement would not probably be as great as might appear on first consideration. For the adjustment of the daily supply, assuming that on any given day the power taken is not much greater than the total available from the tide on that day, the reversible turbines would be distinctly economical, but if the full daily demand is greater than the neap tide supply, then a large amount of the power will have to be stored during the days when the tide is approaching the spring tide, the reservoir will have to be large and pump power in excess of the distributing station turbine power would probably have to be available. Further, turbines and pumps might have to be worked simultaneously. On such days, during the tidal hours, the total horse-power of the turbines at the barrage will have to be large enough to supply much more than the daily output of the distributing station, and a large amount of extra plant will have to be provided, both at the barrage and at the subsidiary station.

All things considered it is probable, however, that reversible pumps connected to rotors which could either be direct current motors or alternating current generators, would lead to the most economical solution as far as hydraulic plant is concerned, but the final answer to the question as to whether it is worth while installing reversible turbines will have to be made when it is shown that such a turbine can be economical as a turbine and as a pump, and when the capacity of the station has been fixed. The necessity for a high level reservoir of very considerable capacity, if the tidal power of the estuary is to be utilised economically, means in addition to a very large expenditure on civil engineering works in the estuary, large expenditure on this reservoir within a few miles of the junction of the Severn and the Wye. How far it will pay to incur expense in connection with high-level reservoirs for storage, and what their capacity should be, can clearly only be determined on reference to the probable cost of all other works. Thus, if the necessary minimum capital outlay at the

* Paper read before Section G of the British Association at Edinburgh, September 9, 1921

barrage is £A, the capital outlay for machinery is £B, that for machines, lines, &c., outside the barrage, £C, and that for the overhead reservoir is £D, then the total annual charge is

$$a\,A + b\,B + c\,C + d\,D$$

where a, b, c and d are interest, repairs and depreciation charges. The annual cost per unit is

$$\frac{a\,A + b\,B + c\,C + d\,D}{N}$$

It is clear that if the denominator N can be considerably increased by increasing D, even though the overall efficiency of the system falls, the final cost per current can be diminished.

For example, suppose the cost of the barrage is 10,000,000*l.*, the total cost of the machinery to give an output of 300,000 h.p. is 18,000,000*l.*, and the cost of the reservoir 5,000,000*l.*, then if by doubling or even trebling the cost of the reservoir the power can be increased by, say, 50 per cent., the cost of the power per unit will have been considerably reduced.

TABLE I.—*Showing the Minimum Estimated Horse-Power and Horse-Power Hours to be obtained from 10-ft. diam. Turbines for a Spring Tide of 40 ft. Initial Head, 6·5 ft.; Final Head, 6·5 ft.; Mean Head, 17·9 ft.*

Time hours.	Head.	$\frac{2}{h^{\frac{1}{2}}}$	H.P. $\propto h^{\frac{3}{2}}$.	Revs. $\propto \sqrt{h}$	H.P. for 250 turbines × 10⁶.
0	6·5	16·6	800	34·4	0·2
	11·0	36·0	1,730	44·5	0·44
	17·0	70·0	1,370	55·5	0·84
	22·0	103·0	4,950	63·0	1·24
	26·0	132·0	6,350	68·5	1·58
	27·2	142·0	6,830	70·0	1·71
	26·0	132·0	6,350	68·5	1·58
	22·0	103·0	4,950	70·0	1·24
	15·0	58·0	2,780	52·2	0·697
6·7	6·5	16·6	800	34·4	0·2

TABLE II.—*Half-Tide System. Working Head* $= \frac{\text{Tidal Range.}}{2}$

Day of month.	Tidal range.	W.H.P. hours per tide.	W.H.P. hours per day.	H.P. per. 6-hour day
	ft.			
0 14	16·0	1·445 × 10⁶	2·89 × 10⁶	481,600
1 13	17·19	1·66 × 10⁶	3·32 × 10⁶	553,000
2 12	20·52	2·375 × 10⁶	4·75 × 10⁶	791,000
3 11	25·33	3·615 × 10⁶	7·23 × 10⁶	1,205,000
4 10	30·67	5·29 × 10⁶	10·58 × 10⁶	1,763,000
5 9	35·48	7·075 × 10⁶	14·15 × 10⁶	2,358,000
6 8	38·81	8·45 × 10⁶	16·90 × 10⁶	2,816,000
7	40·0	9·00 × 10⁶	18·00 × 10⁶	3,000,000

TABLE III.—*Rate of Fall of Basin Constant.*

Tidal Range.	Mean Head.	Maximum Head.	Fall in Basin.	Working Period Per Day.	Minimum Head.	Horse Power Hours per Tide Available.	H.P. per Day Mean Rate.
ft.	ft.	ft.	ft.	hours.	ft.		
16	9·3	10·4	8	9·0	6·5	1·675×10⁸	372,500
40	25·4	35·5	8	15·7	6·5	4·58×10⁸	583,000
40	20·0	27·8	20	12·0	10·0	9·00×10⁸	1,500,000

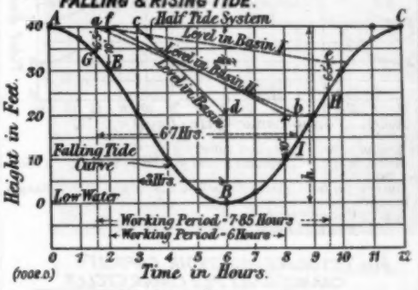
One point that should not be overlooked is that tidal waters will be brackish, and, therefore, if the tidal water is to be pumped to the high-level reservoir, this must be sufficiently watertight to prevent the possibility of the contamination of the underground water supply of the district.

Instead of making a high-level reservoir it might be possible, as an engineering job, to enclose part of the basin by suitable dams and thus to have a number of basins in which the water can be maintained at levels which could be so arranged to give a more continuous constant supply than one basin can give on any day, but it is very doubtful indeed if such a scheme could utilise anything like the same proportion of the available energy as the high-level reservoir scheme, and it is possible that the capital cost per annual unit of power would be much greater.

Assuming, therefore, for the time being, that such a reservoir can be constructed, what might be expected from the Severn scheme and what hydraulic machinery will be required? We shall assume that there is no really serious difficulty in constructing a suitable concrete barrage which will house the turbines. A very careful examination of the river bed must be undertaken before deciding upon any site. It is possible to utilise both the falling and rising tide to produce power, but it is very doubtful indeed if anything would be gained by this at the Severn. Fig. 3 shows a very rough diagrammatic sketch of an arrangement of turbines in the barrage whereby both the falling and the rising tide could be utilised without reversing the turbines, or it can be equally well used, if desired, for the falling tide only. If the ebb tide only is used, no sluice would be required on the down stream face of the dam, and it could thus be more easily protected; the discharge openings could no doubt be placed below water level at spring tides and thus would be entirely protected. Gates could easily be provided at the discharge end of the channel A B, and this channel could be dammed off and pumped dry whenever necessary. For this reason, and for hydraulic reasons, also, it will be an advantage to use the flow of the ebb tide only. By allowing the flood tide to pass through the channels A B, if not through the inlet channels C D, silting near the up stream face of the dam may be prevented, and thus the discharge channel ought probably to have a gate at both ends. For the same reason, it ought seriously to be considered whether the inlet channel C D should not also have gates at both faces of the dam. Satisfactory protecting sluices can be designed to resist the wave action.

There would, in addition, be large automatic sluices in the barrage through which the incoming tidal waters could pass through the barrage. Assuming then the turbines to be producing power only when the tide is falling, to arrive at an estimate of the power available in kilowatt hours (or horse-power hours) per day, it is necessary to know the range of tide for each day and the quantity of water to be taken from the upstream basin, and it is in addition necessary to fix the mean head under which the turbines work. If A is the mean area of the basin in square feet, h the rise of tide on any given day in feet, kh the fall of the level of the water in the basin

Fig. 4. SPRING TIDES. TIDAL CURVE FOR FALLING & RISING TIDE.



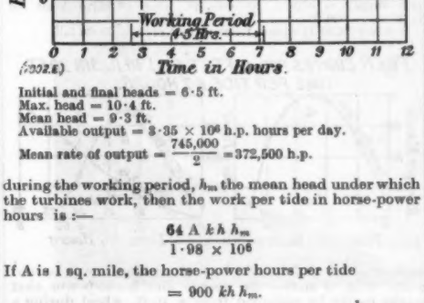
I.

Initial and final heads = 6·5 ft.
Max. head = 35·5 ft.
Mean head = 25·4 ft.
Available output = 9·16 × 10⁶ H.P. hours per day.
Mean rate of output = 583,000 h.p.

II.

Initial and final heads = 10 ft.
Max. head = 27·8 ft.
Mean head = 20 ft.
Output = 9·00 × 10⁶ H.P. hours per tide.
Output = 18 × 10⁶ h.p. hours per day.
Mean rate of output = 1,500,000 h.p.

Fig. 5. NEAP TIDES. TIDAL CURVE FOR FALLING & RISING TIDE.



Initial and final heads = 6·5 ft.
Max. head = 10·4 ft.
Mean head = 9·3 ft.
Available output = 3·35 × 10⁶ h.p. hours per day.
Mean rate of output = $\frac{745{,}000}{2}$ = 372,500 h.p.

during the working period, h_m the mean head under which the turbines work, then the work per tide in horse-power hours is :—

$$\frac{64\,A\,k\,h\,h_m}{1{\cdot}98 \times 10^6}$$

If A is 1 sq. mile, the horse-power hours per tide

$$= 900\,k h\,h_m.$$

Let the fall kh and the mean head h_m be each $\frac{h}{2}$, Fig. 4; then the period of working during a tide will be, say, three hours,* the fall of the basin level being approximately shown by the line *cd*, and the mean horse-power available per square mile of basin during this period of three hours per tide will be

$$\frac{300\,h^2}{4} = 75\,h^2.$$

If h is 40 ft., the horse-power hours per tide per square mile of basin $= \frac{900 \times 1{,}600}{4} = 0{\cdot}36 \times 10^6$ and for an area of 25 sq. miles $= 9 \times 10^6$ h.p. hours per tide; the constant horse-power will be 3,000,000.

If, instead of using the half tide system, the turbines are started when the head is 6·5 ft., Fig. 4, and shut down when the head is 6·5 ft. and the fall of the tide is h_1 (8 ft.), then, for a 40-ft. tide, the working period is 7·85 hours, the maximum head under which the turbines work is 35·5 ft., the mean head is 25·4 ft., and the horse-power hours per tide is 4·58 × 10⁸. The mean horse-power during this period is 583,000.

If *ab* is taken as the surface fall through the turbines, the mean head is 17·9 ft., the basin fall is 20 ft., and for an area of basin of 25 sq. miles, the

$$\text{horse-power hours per tide} = 22{,}500 \times 17{\cdot}9 \times 20 = 8 \times 10^6.$$

The time of working is 6·70 hours and the mean water horse-power is 1,200,000. Assuming turbines of 75 per cent. efficiency this would be 900,000 b.h.p. or, say, 850,000 electrical horse-power.

If now, however, the neap tide curve, Fig. 5, be considered (in the figure it is taken as 16 ft.) it will be seen that, assuming again a minimum head of 6·5 ft. and a fall of 8 ft., the maximum head is 10·4 feet, the mean 9·3 ft., and the average output per day is 3·35 × 10⁶ h.p. hours, or 1·175 × 10⁶ h.p. hours per tide. The mean horse-power is 0·372 × 10⁶. So that a minimum of 372,000 h.p. at the turbines, or, say, 280,000 h.p. at the dynamos, can be obtained on any day for nine hours, or, say, from 200,000 h.p. to 220,000 h.p. on the distributing lines. The approximate water horse-power at any instant on any day can be obtained by drawing up tables similar to Tables I, II and III.

It is clear that if there is to be anything like a constant output from the scheme, or power is to be obtained when the tide is not running, a storage system of some kind is very necessary. Suppose a mean of 250,000 h.p. is obtained from the barrage at neap tide for nine hours per day, say, from 3.30 a.m. to 8, and from 3.45 p.m. to 9.15 at night. If the ordinary demand hours for current are supposed to be *between* 8 a.m. and 6 p.m., then on this day about 90 per cent. of the energy will have to be obtained from the high-level reservoir. This can, of course, be easily stored on those days when the barrage turbines are giving more than 200,000 h.p., and, provided sufficient pumping plant is arranged, the turbines in the barrage that will give about 342,000 h.p. at neap tides, will give the necessary power to drive the pumps.

Let it be supposed that the reservoir has to give a full day's maximum supply, and suppose high head turbines are provided of sufficient capacity to do this. If Q is the capacity of the reservoir, H the reservoir head, and the efficiency from reservoir to electrical output is 72 per cent., the water horse-power hours per day to be supplied from the reservoir are

$$\frac{250{,}000}{0{\cdot}72} \times 9$$

$$= 3{,}125{,}000.$$

The minimum capacity of the reservoir, assuming H is 500 ft., would then be

$$Q = \frac{3{,}125{,}000 \times 1{\cdot}98 \times 10^6}{64 \times 500}$$

$$= \frac{12{,}475 \times 10^6}{64}$$

$$= 200 \times 10^6 \text{ cub. ft., nearly.}$$

Allowing a fall of surface of 40 ft., a reservoir of 5 × 10⁶ sq. ft. area, or nearly one-fifth of a square mile, would be required.

As already pointed out, Fig. 1, curve A B C D E, shows the actual variation of tide during the month of January, 1921. It will be seen that the maximum range is slightly higher than 40 ft. at spring tide and greater than 16 ft. at neap tide. The mean head for this curve for the month is about 29 ft.

Assuming then a half-tide fall for each day and a constant head of half-tide, the horse-power curve is F G H K L. The actual horse-power hours on any day, whether half-tide or other system is used, will not vary very much as long as the fall in the basin is kept constant.

The mean square of the heads is about 890. Fig. 6 shows the water horse-power that can be obtained per day assuming a sine curve for a 14-day period, a 16-ft. tide at the neaps and 40 ft. at the spring tides.

If suitable storage could be provided, it would appear that there should be easily available for a 10-hour working day, assuming for the whole system an average of 55 per cent. efficiency, a mean output of not less than 500,000 h.p. for a 10-hour working day. This capacity will have to be much greater than that which insures a daily supply corresponding to the neap tide supply. Such curves as Fig. 1 should be taken for at least 12 months before the reservoir capacity is finally fixed.

In connection with this it should be clearly recognised that when power has to reach the distributing station by means of the service reservoir, the efficiency is less than 45 per cent., and the more the mean load exceeds the neap tide output the less the overall efficiency. Again it should not be overlooked that the barrage turbines can only produce power at the will of the tides, and thus at those times of the day when the load is heaviest the barrage turbines may not be at work. For example, assume a steady demand of N horse-power hours per day by the distributing station (say, 5 × 10⁸). The actual horse-power available for the transmission lines will be less than this by any losses incurred in the station.

Let N_1 = water horse-power hours available at the barrage per day.
N = horse-power hours entering the distributing station (assumed later as 5 × 10⁸).
M_1 = Water-horse-power hours leaving reservoir when required, per day.
M = Water-horse-power hours entering distribution station, per day from the reservoir.
$N + M = 5 \times 10^6$ horse-power-hours per day. Assuming for the sake of argument the losses as on Fig. 2.

* This is on the assumption that the tidal fall is represented by a sine curve.

Approximately,

$$M^1 = \frac{M}{0{\cdot}75 \times 0{\cdot}95} = 1{\cdot}4\ M,$$

and

$$N^1 = \frac{N}{0{\cdot}95 \times 0{\cdot}95 \times 0{\cdot}75} = 1{\cdot}48\ N.$$

When $N^1 < 1{\cdot}48\ N$ water is taken from storage reservoir. Amounts per day :—$M = 5 \times 10^6 - N$. h.p. hours.

$$= 5 \times 10^6 - \frac{N^1}{1{\cdot}48}$$

Then

$$M^1 = 1{\cdot}4 \left(5 \times 10^6 - \frac{N^1}{1{\cdot}48}\right)$$

When $N^1 > 1{\cdot}48\ N$ the surplus horse-power hours are available for filling the reservoir.

The horse-power hours that can be given to the pumps are :—

$N^1 - \frac{5 \times 10^6}{0{\cdot}67}$. The h.p. hours entering the reservoir

$$= \left\{N^1 - \frac{5 \times 10^6}{0{\cdot}67}\right\} \left\{{\cdot}75 \times {\cdot}95 \times {\cdot}95 \times {\cdot}75\right\}$$

$$= {\cdot}48 \left(N^1 - \frac{5 \times 10^6}{0{\cdot}67}\right)$$

If then H_r is the reservoir head, the increase of energy capacity of the reservoir per day is :—

$$\frac{w\ Qc\ H_r}{1{\cdot}98 \times 10^6} \text{ h.p. hours.}$$

where Qc is the change of capacity in cubic feet. Then

$${\cdot}48 \left(N^1 - \frac{5 \times 10^6}{0{\cdot}67}\right) = \frac{w\ Qc\ H}{1{\cdot}98 \times 10^6}$$

When the reservoir is giving water to turbines :—

$$1{\cdot}4 \left(5 \times 10^6 - \frac{N^1}{1{\cdot}48}\right) = \frac{w\ Qf\ H}{1{\cdot}98 \times 10^6}$$

where Qf is quantity leaving per day.

From these equations Qc or Qf can be calculated for each day and a curve of daily change of capacity for a lunar cycle, Fig. 7, can be plotted. A sine curve for 14 days has been assumed for the tidal rise. Then the minimum quantity of water that has to be supplied per lunar change is the shaded area. The pumps will supply water on days between A and B, while between B and C the reservoir must supply water to the turbines.

If A E F B is approximately made equal to the shaded area under B C the minimum capacity of the pumps or reversible turbines can be obtained. (Pipe line losses are not particularly differentiated.)

The quantity of water to be supplied per 14 days to the reservoir can be pumped on any number of days desired between A and B. Having fixed the days on which pumping shall take place, the mean rate of delivery per day can be obtained and the horse-power of the pumps determined. Assuming, for the moment, a half-tide system, the pumps could work six hours per day, or for a longer period on the variable head system. The mean power that will have to be supplied on the pumping days would then be about 480,000 h.p., for which at least 6×10^6 w.h.p. hours per day will be required at the barrage.

	H.P. hours per day.
Horse-power-hours at barrage for pumps	6×10^6
Horse-power-hours at barrage for distributing station	$7{\cdot}4 \times 10^6$
	$13{\cdot}4 \times 10^6$

= 2·2 million horse-power for six hours per day or, assuming an average of nine hours per day = 1,500,000 h.p.

The number of turbines required, if working on a half-tide system, would be from 600 to 900, depending upon the horse-power of turbine, *e.g.*, the turbines 10 ft. and 15-ft. diam., respectively, have horse-powers at 17·8 ft. head, of 2,400 and 3,600, respectively. It would be possible, I think, even to increase these horse-powers per turbine, but, as far as I know, the turbines I have in mind have not yet been constructed. If, however, we work on the system of a range from 6·5 ft. head to 6·5 ft. head and a fall of half a tide, the number of turbines will be only from 400 to 600, depending upon the size of the turbine determined upon.

At neap tides, the total energy available is 372,000 h.p. for nine hours per day. The mean head is 9·3 ft., or at neap tides, 481,600 h.p. could be produced for six hours per day on the half-tide system. (See Table II.)

For a mean head of 9·3 ft., each turbine has a horse-power of, say, 1,000 (see Table IV), then the number of turbines required would be $\frac{372{,}200}{1{,}000} = 372$.

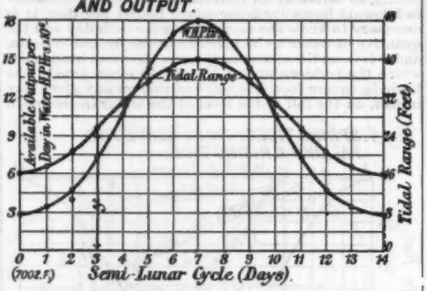
If we work on the half-tide system the number of turbines to give 481,600 h.p. at 8 ft. head would be much greater. So that from this point of view it will be better to work on the variable head system. If the demand at any time increases, there will be turbines available to meet the peak load.

Turbines at the Barrage.—The type of turbine to be used at the barrage must almost essentially be the modified Francis turbine, known as the mixed-flow turbine. The guide blades for these can be made fixed or movable. If the former, then for economy, the speed should be changed as the head is altered. If the latter, then the speed can be kept constant for a considerable range of power while the efficiency will probably be kept between 68 per cent. and 80 per cent. If the guide blades are fixed and the speed varied, the efficiency can probably be kept more constant. In this case, the principle of similarity shows that the speed should vary as $h^{\frac{1}{2}}$, where h is the working head, and the horse-power will vary as $h^{\frac{3}{2}}$. Table IV shows the horse-power that might be expected from a 10-ft. diam. turbine, about 5 ft. 6 in. to 6 ft. deep at various heads. The speeds might vary between 30 r.p.m. and 60 r.p.m. per minute. It would be possible to increase these speeds to a maximum of, say, 80 revs. per minute, but it is doubtful if much would be gained. By making the guide blades movable, a constant speed of from 50 r.p.m. to 70 r.p.m. could be obtained. The velocity of whirl will be much less than the velocity of the wheel periphery, or in other words, the turbine blade at inlet will be well set back from the tangent. Fig. 8 shows the speeds and horse-power that might easily be obtained from a 10-ft. wheel during a 6·7 hours period for a spring tide of 40 ft. rise.

Turbines and Pumps at the Subsidiary Station.—The centrifugal pump is simply a reversed reaction turbine, and there would appear to be no satisfactory reason why the same machines should not be used as pumps, and when reversed as turbines. The head from the reservoir will be probably of the order of 500 ft. or 600 ft., and for this head if there were no question of pumping, Pelton wheel turbines would be generally used. In the case under discussion the use of reaction turbines to be reversed as pumps is possible, and considerable capital outlay will be saved. This type of machine working under a head of 500 ft. or 600 ft., has not been yet developed, but it should be possible. These machines as pumps can be run at constant speed, as the head against which they are pumping will be reasonably constant. For starting up the pumps, it may be desirable to be able to run the motors beyond the steady speed, and for this reason direct-current motors may have a distinct advantage. The whole question of the pumps and turbines at this station would have to be very carefully considered from the theoretical and practical aspects, and such plant installed as will allow of the most efficient use of the reservoir. It has been shown that the maximum mean daily output depends upon the reservoir capacity, and, further, that power obtained from the reservoir costs far more in water horse-power at the barrage than power supplied direct to the distributing station. The highest efficiency possible is, therefore, important in the pumps at the subsidiary station.

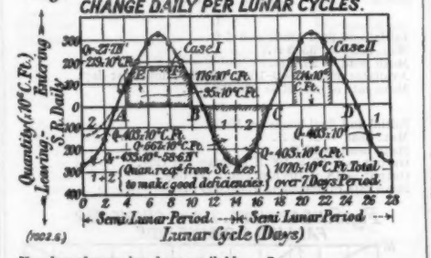
Finally, it would appear from these preliminary, calculations, that it should be easily possible to depend upon a minimum mean output per day at the barrage of $2{\cdot}5 \times 10^6$ h.p. hours per day, without any high-level reservoir, but the horse-power would vary with the variation of the tide. If this could be used at its time of generation, there would be no necessity for an auxiliary reservoir, but it might be necessary to have expensive electrical plant in order to keep a constant potential on the distributing line. It is hardly possible, however, to conceive of load on the distributing system being reasonably perfectly adapted to this daily variation in power, and also the demand being changed so that it coincided with the changeable hours day by day when the tide is available for doing work. The only hope of using the load economically as produced would be at special chemical and metallurgical works where the shifts might perhaps be adapted to the vagaries of the tide. This does not appear to be a very likely possibility.

Fig. 6. BARRAGE TURBINES. TIDAL RANGE AND OUTPUT.



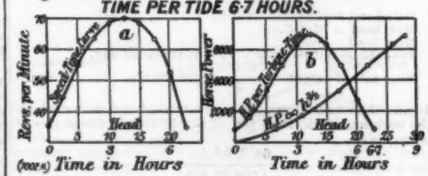
Area of basin = 25 square miles.
Half-tide system : working period = 3 hours per tide = 6 hours per day.
Output period ∝ (Tidal Range)^3 = 225 × A × (Tidal Range) h.p. hours.
H.P. = $\frac{\text{Horse-power hours.}}{\text{Number of hours.}}$

Fig. 7. STORAGE RESERVOIR CAPACITY CHANGE DAILY PER LUNAR CYCLES.



Number of pumping days available = 7.
Can supply the 1070×10^6 as follows :—
Case I :—2 days at 95×10^6 cub. ft. = 190×10^6 cub. ft.
5 days at 176×10^1 cub. ft. = 880×10^6 cub. ft.
= 1070×10^6 cub. ft.
Necessary h.p. of pumps = 480,000.
Necessary w.h.p. hours at barrage = 6×10^6.
Case II.—5 days at mean rate, 214×10^6 cub. ft. = 1070×10^6 cub. ft.
Necessary h.p. of pumps = 580,000.
Necessary w.h.p. hours at barrage = $7{\cdot}3 \times 10^6$.
Demand at distributing station = 5×10^6 h.p. hours per day.
Minimum capacity of storage reservoir to ensure continuity of this supply = 1070×10^6 cub. ft. when effective head for turbines = 500 ft.
Equivalent to 1¼ square miles surface area × 25 ft. fall.

Fig. 8. CURVES FOR 40 FT. S.T. FALL IN BASIN 20 FT. TIME PER TIDE 6·7 HOURS.



The whole scheme is worthy of consideration in a scientific gathering of this kind, but considering the large capital outlay on civil engineering works, on machines, and the possibilities of cost of removing silt and loss to present interests, the whole scheme would have to be thoroughly investigated before a final policy is embarked upon. Such inquiry is, however, well worth instituting, and should be faced in a hopeful and enthusiastic way, as if it proves economically to compare reasonably well with heat-engine power distribution stations, it may be of considerable significance from the point of view of conserving national resources and preventing one section of the community from holding up our industries, and it may well encourage a greater use of electrical power for many purposes other than those at present using such sources of energy.

Before decisions are come to, then, relative to the use of any such tidal estuaries for power purposes :—

(1) Careful hydrographic records must be taken, regard being given to the problem of silting.

(2) Careful hydrographic surveys made. From these the quantity of the water per tide would be available. The effective area of the basin at different levels is very important.

(3) The geology of the district of the proposed dam and of the high level reservoir must be examined.

(4) Curves must be got out showing the available energy per tide for a period of, say, 12 months.

(5) The cyclical 14 days variations must be carefully considered, as they may be by no means constant during the year.

(6) The capacity of the reservoir must be considered in relationship either to the daily or to the 14-day cyclical variation, whichever is possible.

(7) Turbines on the barrage must be such that they can be worked efficiently, in the case of the Severn Estuary, at heads varying from, say, 6 ft. to 36 ft.

(8) The number of turbines must be considered in relationship to the power required at the distributing station and also to take advantage of the excess energy over and above that required for the distributing station. This will be very seriously affected by the power demand, and also by the storage determined upon in the high-level reservoir.

TABLE IV.—*Output of Turbines.*

Head.	Diameter of wheel.	Depth of Inlet face.	R.P.M.	H.P.
ft.	ft.	ft.		
35·5	10	6·0	68·5	6,800
35·5	15	6·0	45·7	10,200
27·8	10	6·0	60·6	4,720
27·8	15	6·0	40·3	7,080
27·5	10	6·0	60·0	4,500
27·5	15	6·0	40·0	6,750
27·5	15	7·5	40·0	8,437
25·4	10	6·0	58·0	4,120
25·4	15	6·0	38·6	6,180
20·0	10	6·0	51·4	2,820
20·0	15	6·0	34·2	4,230
10·4	10	6·0	37·0	1,073
10·4	15	6·0	24·65	1,612
10·0	10	6·0	36·0	1,018
10·0	15	6·0	24·0	1,527
9·3	10	6·0	35·0	912
9·3	15	6·0	23·0	1,365
8·6	10	6·0	33·6	820
6·5	10	6·0	29·2	532
6·5	15	6·0	19·43	800
6·0	10	6·0	28·0	472
6·0	15	6·0	18·6	710

ELECTRICITY UNDERTAKINGS.—*The Electrician* Tables of Electricity Undertakings, 1921, have recently been issued by *The Electrician*, in the shape of a book bound in blue cloth, measuring 12½ in. × 10 in., and containing 126 pages. The matter is arranged alphabetically according to towns, the information given comprising the date when supply commenced, the names of the owners and engineer, the system, voltage, load, plant, price per unit, &c., for the British and the Colonial electricity supply undertakings. Similar information is also given for a large number of electricity supply works. The present is the 34th annual edition, and its price is 10*s.* and 10*s.* 9*d.* post free.

AN EXPERIMENTAL INVESTIGATION OF THE MECHANICAL PROPERTIES OF STEELS AT HIGH TEMPERATURES.*

By E. L. DUFUY (Paris).

(*Concluded from page* 394.)

Steel containing 1·25 *per cent. of Carbon.* (Figs. 27 to 31.)—Cast steel containing 1·25 per cent. of carbon is exceedingly brittle in the cold. In certain bars fracture occurs in the heads of the test-pieces, which are 25 mm. in diameter, without the body of the test-pieces, which are 13·8 mm. in diameter, having undergone any appreciable deformation. Uniform fractures do not begin to occur after 500 deg. has been reached. The breaking stress starting at 100 kg. per square millimetre for heat-treated cast metal, and at 106 kg. per square millimetre for rolled and heat-treated metal, rises rapidly up to about 300 deg., at which temperature it reaches 110 kg. per square millimetre in the case of the heat-treated cast metal, and 130 kg. per square millimetre for the heat-treated rolled metals. It then falls uniformly to about 18 kg. per square millimetre at

Fig. 27. CARBON, 1·25 PER CENT

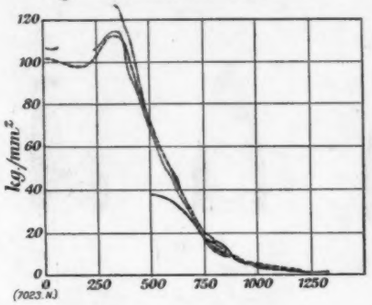
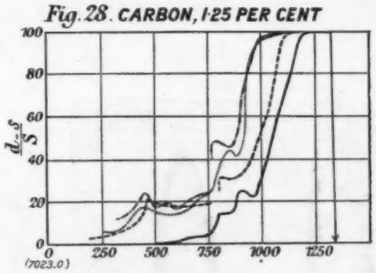


Fig. 28. CARBON, 1·25 PER CENT



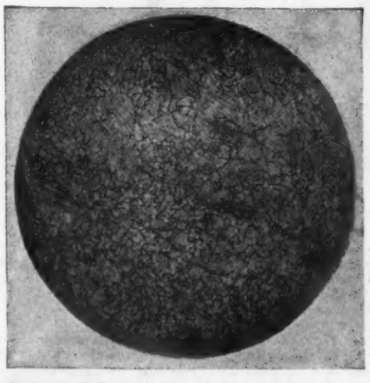


FIG. 30. SAME AS FIG. 29, HEAT-TREATED AND ETCHED WITH PICRATE OF SODA.

and 450 deg., and remains in the neighbourhood of this amount up to 775 deg., oscillating a little at 600 deg. From 775 deg. it rises suddenly, remains at about 45 per cent. up to 875 deg. (or 30 per cent. in the case of the heat-treated cast steel), and then begins to increase until it reaches 99 per cent. at about 1,000 deg. At 1,356 deg. it suddenly falls to nil.

If the whole of the results relating to various grades of steel be examined, it will be seen that when the temperature increases, the breaking stress to begin with undergoes a slight decrease. After this it rises, showing a maximum at about 300 deg.—that is to say, in the maximum in the curves relating to tensile strength. There then occurs at about 450 deg. a rapid increase, which is the more marked in proportion as the metal contains less ferrite. After a slight step, the reduction in area diminishes slightly, and then increases up to 775 deg. From this point the various grades of steel behave differently, according to their percentage of carbon. In the case of dead mild steel, after a well-marked increase the curve of the reduction of area falls rapidly up to about 875 deg. It then shows certain oscillations; attains 100 per cent. in the vicinity of 1,050 deg., and ultimately falls to zero simultaneously

FIG. 29. STEEL WITH 1·25 PER CENT. OF CARBON, AS CAST. SECTION AT RIGHT ANGLES TO THE LONGITUDINAL AXIS OF TEST BAR, ETCHED WITH NITRIC ACID IN ALCOHOL.

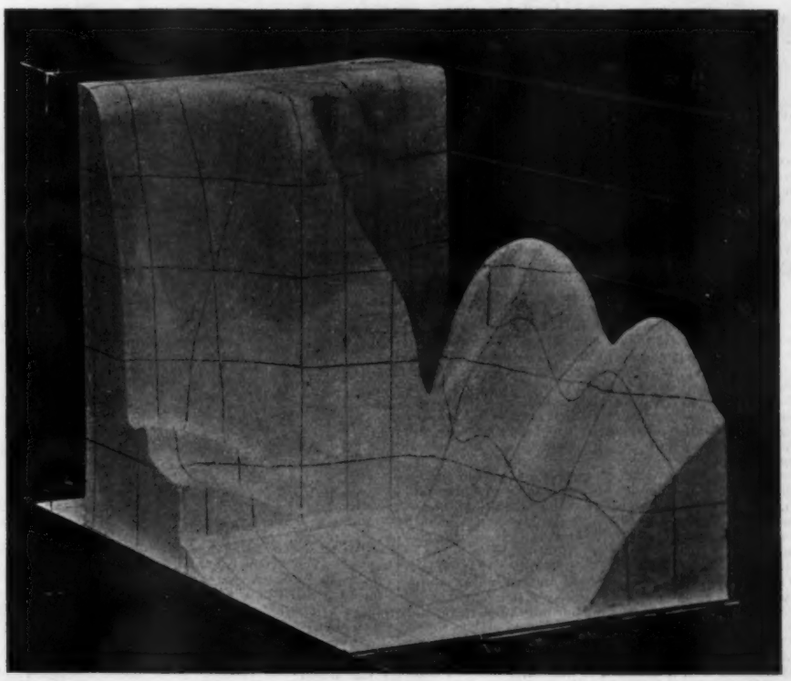


FIG. 31. METAL AS CAST. VARIATION OF THE REDUCTION OF AREA IN ITS RELATION TO THE TEMPERATURE AND TO THE PERCENTAGE OF CARBON.

760 deg. At this temperature the curve exhibits a very slight discontinuity, followed by a few slight oscillations. It falls slowly thereafter up to 1,350 deg., where it suddenly drops from 3 kg. per square millimetre to nil. The curves relating to the reduction in area possess more character. In regard to the metal as cast, the curve of the reduction of area starts from nil to 490 deg. It rises with a few oscillations up to 775 deg., at which temperature it amounts to 7·5 per cent. It then remains in the neighbourhood of 15 per cent. up to 875 deg., when after a slight oscillation it rises to 99 per cent. at about 1,200 deg. In the case of the heat-treated or rolled steel the reduction in area, which in the cold is about 5 per cent., rises to 20 per cent. between 300 deg. and 450 deg., remains in the neighbourhood of this amount up to 775 deg., oscillating a little at 600 deg. From 775 deg. it rises suddenly, remains at about 45 per cent. up to 875 deg. (or 30 per cent. in the case of the heat-treated cast steel), and then begins to increase until it reaches 99 per cent. at about 1,000 deg. At 1,356 deg. it suddenly falls to nil.

If the whole of the results relating to various grades of steel be examined, it will be seen that when the temperature increases, the breaking stress to begin with undergoes a slight decrease. After this it rises, showing a maximum at about 300 deg.—that is to say, in the vicinity of blue heat. From this point there is a uniform decrease, with perhaps a slightly marked anomaly in the neighbourhood of 450 deg. to 550 deg., this uniformity continuing up to just below 750 deg. A discontinuity then occurs, followed to begin with, in hypo-eutectoid steels, by a slight lowering in the breaking stress, and then an increase, giving a representative and characteristic U-shaped curve, whereupon, after a slight flattening, the breaking stress begins to fall until the commencement of the liquidus, where it suddenly falls to zero. In the case of eutectoid steels, the U-shaped branch does not occur, while in hypo-eutectoid steels it is superseded by a curve showing a bend at about 875 deg.

These different anomalies are even more marked in the case of the curves relating to reduction of area. There is, to begin with, a slight fall in the reduction of area, a minimum at about 300 deg., corresponding with the with the breaking stress. The minimum in the neighbourhood of 900 deg. is the more marked in proportion as the percentage of carbon is higher, and in the case of the eutectoid steel the curve relating to the reduction of area begins to rise from 600 deg. onwards, and attains 100 per cent. at about 760 deg. In the case of steel containing 1·25 per cent. of carbon there occurs once again a branch of the curve, which is almost horizontal and constitutes the step between the regions of low reduction (at temperatures below 760 deg.) and those at which they reach 100 per cent. In order to summarise these results, the author has constructed a diagram for the metal as cast (surface—reduction in area—carbon—percentage—temperature), Fig. 31. The three-dimensioned figure thus obtained affords an easier method of taking into account the mode in which these properties vary in respect of the two other variables.

* Paper read at the Paris Meeting of the Iron and Steel Institute, Tuesday, September 6, 1921.

To what extent can these results be made to harmonise with the existing diagram of the iron-carbon alloys? There is seen to begin with, and in regard to all the grades of steel under investigation, an initial anomaly at about 750 deg. This temperature is in the neighbourhood of that corresponding with the Ac1 point for rates of heating of the order of those attempted in the author's experiments. It is known, further, that in the case of the steel containing 0·9 per cent. of carbon —that is to say, not presenting any transformation point —this anomaly is the only one observable. An examination of the dead mild steel test-pieces shows, too, that above this temperature the steel still contains ferrite. In the cold, as has been seen, tensile stress begins by deforming the ferrite grains, which become elongated in the direction of the stress; in the case of the steel as cast wherein the grain structure is unusually coarse, the bar, which to begin with exhibits a brightly polished surface, assumes a characteristic roughened appearance. Now, when the breaking temperature at which this appearance ceases to be exhibited is investigated, it will be seen that it is not until 860 deg. has been reached that the specific mode of ferrite deformation ceases to be observed. The anomaly at 750 deg. evidently corresponds, therefore, with the disappearance of the pearlite, which is transformed into austenite with 0·9 per cent. of carbon, that is to say, at the A1 point.

Dead soft steels show, between 750 deg. and 860 deg. fresh modifications in their properties, but contrary to what occurs at the A1 point, the transition takes place progressively. Now, as has already been seen, it as at the latter temperature that an alteration in the exterior appearance of the bars is observed. The roughened effect disappears suddenly at 860 deg. The appearance of this variation presents close analogy with that of magnetism, which diminishes gradually within the same interval, that is, up to the A2 point. It would appear, therefore, that there is some correspondence between this variation and the transformation point. Above Ac2 the appearance of a broken test-piece is no longer the same; fracture occurs to some extent by separation between the grains, and almost without deformation, the metal yielding almost like a piece of dry indiarubber. This occurrence, which is specially marked in the case of dead mild steels, becomes gradually less marked in proportion as the percentage of carbon increases (Fig. 32).

Steel with 0·55 per cent. of carbon no longer exhibits this variation in properties corresponding with the Ac2 point. The fracture at above 760 deg. exhibits by stages a transition from a smooth appearance to a crinkly appearance (Fig. 33, bars 1, 2, and 3). How can this variation in the mode of deformation before fracture be explained? It is necessary to remember that it is a question here, of a heterogeneous material. At above the Ac1 point hypo-eutectoid steels consist of grains of ferrite in the α or β state (the author only uses the latter term in order to designate the condition of the metal between the two lines A2 and A3 in the diagram, without assigning to it any signification in regard to the allotropic state) embedded in a network of austenite derived from the transformation of the pearlite. When structures, the plasticity and rigidity of which differ, are in juxtaposition with each other, the mechanical properties observed, unless these elements are intimately commingled, are those of the least rigid constituents. As will be seen in the sequel, austenite is distinctly plastic. In admixture with ferrite, either transformed or untransformed, but presenting a higher degree of mechanical resistance it will play the part of a deformable binding medium, similar to the basic constituents of an anti-friction metal. When the carbon is very low (steel with 0·15 per cent. of carbon) the austenite network contains discontinuities, and the mechanical properties are intermediate between those of the two constituents. As the tensile strength of those constituents differs somewhat, the ferrite undergoes an initial deformation before rupture takes place. An examination of the diagrams shows that in the region comprised between A1 and A2 or A3 the breaking stress does not vary greatly in respect of the percentage of carbon, the contraction of area having similar values of the same order in all test-pieces which have undergone similar heat treatments.

The region A2 to A3 is characterised by a rise in the breaking stress, and the metal breaks almost without deformation. If it be allowed that in the β state ferrite has a higher range of flow than it has below Ac2, it would result that fracture would take place in the joints of the austenite, before the ferrite had begun to undergo deformation. In regard to dead soft steel, owing to the minute dimensions of the plastic joints, fracture would occur without appreciable deformation in the metal, that is to say, with a very low degree of contraction of area. It is with this zone that the region of brittleness noticed in forging the metal corresponds. At high temperatures the breaking stress is very low; the metal is wholly plastic, and the broken test-pieces exhibit a sharp needle-shaped point, corresponding with a contraction of area equal to 100 per cent. This region corresponds with that of the austenite. It is only below a temperature in the neighbourhood of the Ac point that this plasticity decreases. Steel containing 1·25 per cent. of carbon does not exhibit a direct transition of its mechanical properties from those corresponding with pearlitic contraction to the plasticity corresponding with the austenitic region. This is because, as a matter of fact, such a metal contains an excess of cementite, which still remains stable at above A1, 2 and 3. The plastic state only corresponds with the total solution of the latter, that is to say, at the point Acm. Finally, the intervention of the liquidus, which deprives the steel of all its consistency, causes it to break without deformation under an infinitely small load, similar to the case of wet sand.

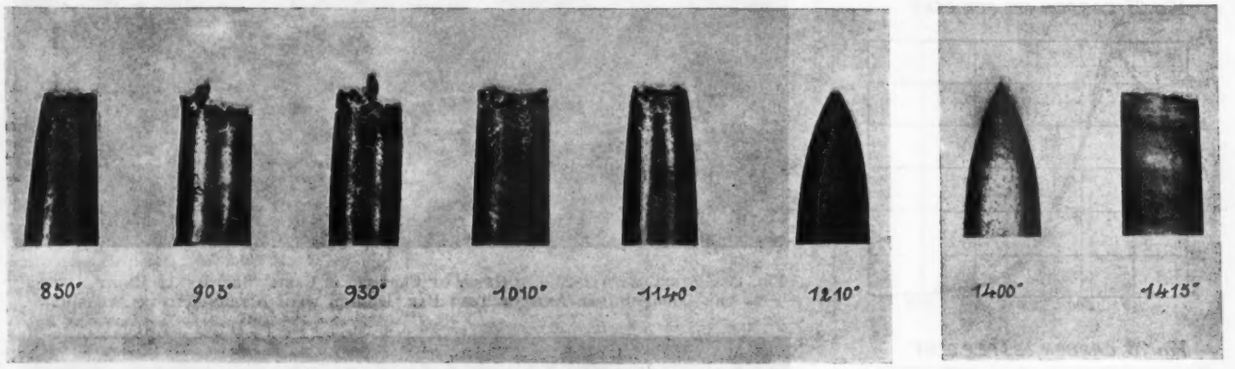


FIG. 32. STEEL 29 (C = 0·15 PER CENT.) AS CAST.

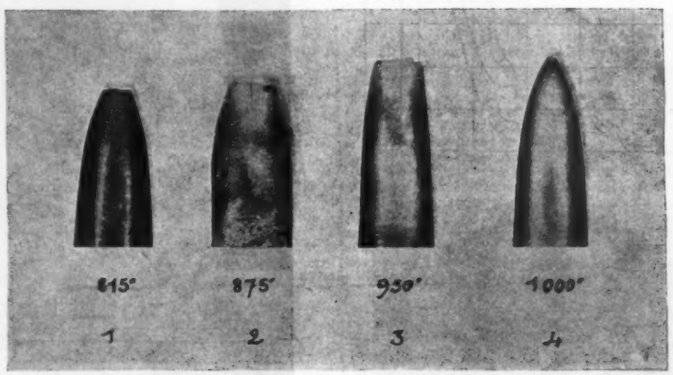


FIG. 33. STEEL 27 (C = 0·55 PER CENT.).

CONCLUSIONS.

The author has, to begin with, taken, in regard to this investigation, the values of the breaking stress and contraction of area as characteristic of the mechanical properties at various temperatures. The results obtained appear to show that the mechanism of fracture is not the same at different temperatures.

The figures obtained cannot therefore be taken as invariable measures of the same phenomenon; it is necessary to regard the curve representing the breaking load or the contraction of area not as a single curve exhibiting a certain number of singularities, but as a series of different curves, plotted one with another on the same diagram. The observed phenomena are therefore fairly complex, for besides the temperature and the composition it is necessary to take into consideration the nature and physical structure of the elements constituting the aggregate. To sum up, steels can be divided as follows:—

1. Below A1 (and having A2 as their limit):
   Dead soft steel: ferrite which undergoes deformation by cleavage before fracture.
   Hypo-eutectic steels: only the ferrite undergoes appreciable deformation; fracture takes place when the pearlite areas come into contact with each other.
   Eutectic steels: fracture almost without any deformation.
   Hyper-eutectic steels: brittleness due to the presence of cementite.
2. Austenitic region:
   No matter what the carbon percentage is, the γ iron is entirely plastic.
3. Region comprised between A1 and A2:
   The plasticity increases with the proportion of γ iron.
4. Region comprised between A2 and A3:
   Fracture almost without deformation owing to the low proportion of γ iron and the brittleness of iron in the β region.
5. Intervention of the liquidus:
   Sudden and simultaneous fall in the breaking stress and the plasticity.

The above investigations were carried out during January-September, 1920, at the Compagnie des Forges de Chatillon Commentry et Neuves-Maisons at Montluçon, under the superintendence of Mr. Girard, head of the testing and metallurgical research department. The author's thanks are due to him for the facilities placed at his disposal for carrying out the work, and he also wishes to place on record his gratitude to Professor H. Le Chatelier, whose valuable advice has been of the greatest assistance.

THE REPAIR OF MOTOR ENGINE CYLINDERS.—The scoring of the cylinder of a motor car is an accident which has necessitated reboring or regrinding the cylinder in order to get the latter into a proper working condition again. When the scoring is really bad these remedies may be inadequate, and a new cylinder has frequently had to be fitted. What appears to be a cheap and effective way of dealing with scored cylinders has been developed by the Melvin Engineering Company, Limited, of 5, Old Compton-street, Charing Cross-road, London, W.C.2, who restore the original form and smoothness of the bore by filling the grooves with a hard alloy. The latter consists of a copper-tin-nickel-antimony mixture, which is melted into the grooves by means of a gas blowpipe, the excess being scraped away to conform with the cylinder curvature. For water-cooled cylinders the alloy has a melting point of 450 deg. C., but for air-cooled cylinders a higher percentage of nickel is used, raising the melting point to 800 deg. C. or 900 deg. C. Cylinders of the latter type are raised to a red-heat before the alloy is put in. The adherence of these alloys to the cylinder walls appears to be all that could be desired, and their hardness at any temperature to which they could be subjected in working conditions seems also to be quite adequate.